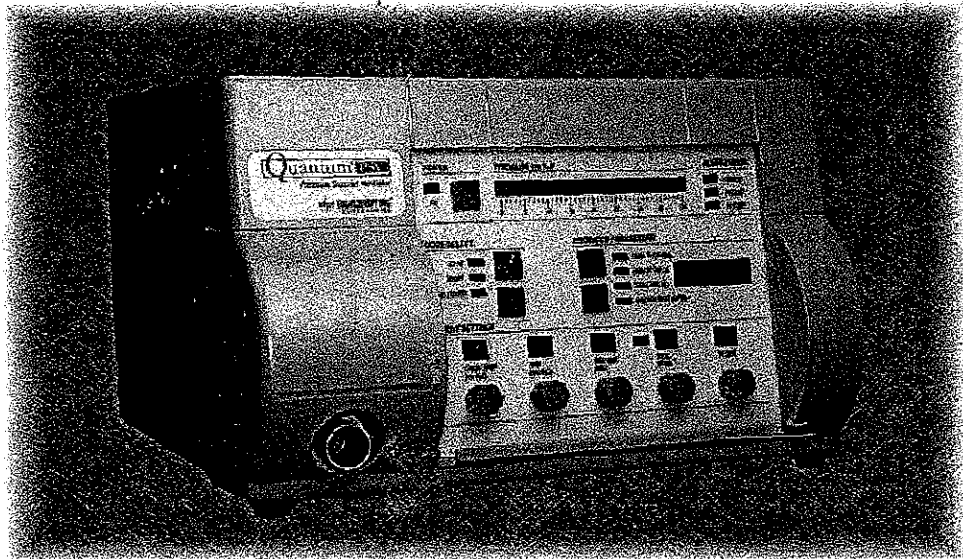


Rockford S.C.

QuantumTM PSV

Pressure Support Ventilator



Service Manual


RESPIRONICS®



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Section 1.0 Introduction	6
About this Manual	
Servicing and Warranty	
Service Location	
Service and Inspection Forms	
Recommended Service, Repair, and Test Equipment	
Engineering Change Orders	
Equipment Inspection	
Authorized Service Centers	
Servicing Guidelines	
 Section 2.0 Warnings and Cautions	 14
Warnings	
Cautions	
ESDS Warnings and Cautions	
 Section 3.0 Specifications and Alarms	 18
Front Panel Controls	
Performance Specification	
Physical Specifications	
Power Requirements	
Output Signals	
Alerts	
Front Panel Visual Indicators	
Rear Panel Visual Indicators	
Rear Panel	
Power Alert	
Patient Alert	
System Alert	
 Section 4.0 Troubleshooting Chart	 24

Section 5.0 Operational Checks	29
Operational Checks	
Using an RT-200	
Visual Inspection	
AC Line Indicator	
Diagnostic Check	
Panel Lock Check	
CPAP/EPAP Control	
IPAP Control	
Low Pressure CPAP Performance Check	
High Pressure CPAP Performance Check	
Risetime Control	
BPM Control	
%I Time Control	
Bar Graph Display Check	
Mode Selection Check	
Pressure Verification	
CPAP Pressure Check	
IPAP Pressure Check	
Spontaneous Mode Check	
Spontaneous/Timed Mode Check	
Approximate Timing Check	
~~Power Alert Check~~	
Patient Alert Check	
System Alert Check	
Estimated Parameters Check	
Communication Port Check	
Analog Pressure Output Check	
Analog Flow Output Check	
 Section 6.0 Preventive Service	 40
Preventive Service Procedures	
Mandatory Engineering Change Orders (ECOs)	
Quality Assurance Checkout Procedures	

Section 7.0 Disassembly, Inspection, and Reassembly	44
Disassembly, Inspection, and Reassembly	
Case Removal and Inspection	
Intake Baffle Removal	
Blower Assembly Removal	
Fan Removal	
Hour Meter Removal	
AC Inlet Removal	
Alarm Battery Replacement	
Controller Board Removal	
Encoder Board Removal	
Power Board Removal	
Front Panel Removal	
Front Panel Bracket Removal	
Alarm Assembly Removal	
Display Board Removal	
Valve Removal	
Sensor Board Removal	
Pressure Switch Removal	
Solenoid Removal	
Old Style Auxiliary Valves	
Noise	
Final Unit Reassembly	
 Section 8.0 ECO Changes	 58
Mandatory Engineering Change Orders	
ECO #: 67266670 U31 Relay Replacement	
ECO #: 6065 Fuse Drawer Change Out	
ECO #: 5850 Valve Replacement	
ECO #: 5769 CPU Board Upgrade	
ECO #: 5557/5505 Hour Meter installation for New Style Back Panels	
ECO #: 5465 Valve Replacement	
ECO #: 5147 Controller Board Upgrade	
 Section 9.0 Run-In	 62
Run-In Requirements	
Guidelines	

Section 10.0 Calibration and Testing	64
Calibration	
Blower/Valve/Sensor Board Calibration	
AC Line Indicator	
Diagnostic Check	
Mode Selection Check	
Pressure Verification	
CPAP Pressure Check	
IPAP Pressure Check	
Spontaneous Mode Check	
Spontaneous/Timed Mode Check	
Approximate Timing Check	
Power Alert Check	
Patient Alert Check	
System Alert Check	
Estimated Parameters Check	
Communication Port Check	
Analog Pressure Output Check	
Analog Flow Output Check	
 Section 11.0 Parts List	 76
Service Kits	
Parts List	
 Section 12.0 Theory of Operation	 80
System Components	
Main Unit Internal Components	
Physical Board Arrangement	
Power Distribution	
Power On/Off Control Subsystem	
Alarm Circuit Subsystem	
Encoder Board	
Display Board	
CPU Board	
Control Board	
 Section 13.0 Schematics	 106

Introduction

Section 1.0

- About this Manual
- Servicing and Warranty
- Service Location
- Service and Inspection Forms
- Recommended Service, Repair, and Test Equipment
- Engineering Change Orders
- Equipment Inspection
- Authorized Service Centers
- Servicing Guidelines

Introduction

About this Manual

▼ This manual is intended for use when servicing the Respironics® Quantum PSV 7700. Sections covering troubleshooting, circuit descriptions, and testing are included. Personnel servicing the Quantum PSV 7700 must be thoroughly familiar with the Quantum PSV 7700 Operating Manual and the ventilator's functions. The information contained within this document is subject to change without notice.

This procedure is written for a technician experienced in volt meter usage, soldering, and electrical troubleshooting. **Do not attempt to repair the Quantum PSV 7700** otherwise. Unauthorized repair voids the warranty. Refer to the Quantum PSV 7700 Operating Manual for complete warranty information.

A **WARNING** notifies when there is a possible hazard or danger to the Patient or Service Personnel.

A **Caution** notifies when possible damage may occur to the device.

Servicing and Warranty

▼ It is recommended that the Quantum PSV 7700 be serviced by an authorized Respironics Customer Satisfaction Center every 800 hours recorded on the hour meter. This allows Respironics Service Personnel to check the performance of the unit, check the electrical integrity, and replace parts as necessary.

Respironics warrants the Quantum PSV 7700 to be free from defects in material and workmanship for a period of one year after delivery, provided that the unit is properly operated, under normal conditions. Respironics makes replacements, repairs, or issues credit for equipment or parts which are found to be defective. The defective unit may be returned prepaid to Respironics after the customer has received approval from Respironics to return the unit.

This warranty does not apply to any unit or individual parts which have been repaired or altered in a way that, in Respironics' judgement, affects the stability or reliability, or which has been subjected to misuse, negligence, abuse, or accident. This warranty does not cover damage which may occur during shipping. If there is any damage during shipping, please contact the carrier or individual who delivered the unit.

Respironics offers a month-to-month maintenance contract on the Quantum PSV 7700. The maintenance contract covers all parts, labor, and loaner ventilators. If a unit is out of warranty, and a maintenance contract is desired, it is necessary for the owner to submit the unit to Respironics or a Respironics distributor for servicing, on a time and material basis, to bring the unit in-line with Respironics standards. The unit may then be placed under a month-to-month maintenance contract.

SECTION 1.0



Introduction

Respironics®, Inc., and Respironics® Georgia, Inc. have a policy of continued product improvement and reserve the right to alter specifications without notice.

▼ The Quantum PSV 7700 may be repaired at any Respironics Customer Satisfaction Center located throughout most of the world. Please call 800/669-9234 for the location of the Respironics Customer Satisfaction Center nearest you.

WARNING: Federal law restricts this device to sale by or on the order of a physician.

▼ Use the following forms and procedures during servicing or inspection of the Quantum PSV 7700:

577-7701-00	Quantum PSV Clinical Manual
1002917	Quantum PSV Service Manual
Field Comm 98-07	Quantum PSV Screening Procedure

Current revisions of these forms and procedures may be obtained from any Respironics Customer Satisfaction Center or by contacting:

Respironics, Inc.
Attention: Technical Services
1001 Murry Ridge Lane
Murrysville, PA 15668
Phone: 1-888-276-0715 • Fax: 1-800-422-5816

Servicing and Warranty (Continued)

Service Location

Service and Inspection Forms

Introduction
**Recommended
Service, Repair, and
Test Equipment**

▼ A complete list of service kits may be found in Section 11.0.

<u>Respironics Part Number</u>	<u>Description</u>
98260	Tie Wrap Gun
90902	Gate Valve Assembly
90037	Pressure Restrictor, PLV
98559	Allen Driver Set
98560	Nut Driver Set
98251	Soldering Station
98577	Fluke Meter/Ohmmeter (Multimeter) Model 45 or equivalent
98144	Solder Wick, 110" Copper
98128	Wrist Strap, Antistatic
98129	Wrist Cord, Antistatic
98906	Cord, Wrist Strap, Grounding
98537	Mat, Table, Antistatic, 2' x 4'
98265	Shunt, 1 Meg Ohm
98561	Pliers, Snap Ring
98565	Heat Gun
7700-18	Test Kit
	Y-Tube Simulator (included in Test Kit)
TS-7700-031	Restricted, Connector, Aprt 22 mm (Test Kit)
TS-7700-032	Unrestricted, Coupler, 22 mm I.D. (Test Kit)
06658	Test Lung, 1 liter
7703	Quantum Remote Unit
	1/8" x 18" long Allen Driver
	Timeter RT-200, OR EQUIVALENT TEST

EQUIPMENT

Training/Test Lung (Michigan Instruments Model 2600I)
Mini-Phono Plug
Torque Control Screwdriver
12" Long #1 Phillips Screwdriver
Pneumotach Flow Meter

Miscellaneous Equipment:

	Wire Cutters
	Needle Nose Pliers
	Regular Pliers
	Straight Blade Screwdriver
	Jewelers Screwdriver Set
	Phillips Head Screwdriver
	Wire Strippers
	Hemostat, 6" Soldering
	Solder, Pure, 60/40
98573	* Magnehelic Gauge, 0-20 cm H ₂ O
98574	* Magnehelic Gauge, 0-150 cm H ₂ O
	* Digital Pressure Manometer (Merical DP200I or equivalent)
302227	* Respironics Digital Manometer
	Flow Source (p/n 7300 or equivalent)

SECTION 1.0

Introduction

* May be used in place of the Timeter RT-200, OR

EQUIVALENT TEST EQUIPMENT

▼ Any ECO not installed in a unit, must be installed during service of the Quantum PSV 7700 unless it is listed as optional in this service manual. ECOs are found in Section 8.0 of this manual.

▼ Respironics recognizes the need for outside centers to maintain their own equipment. To ensure quality service, Respironics has developed a Service Center Certification Program consisting of two parts; facility inspections and personnel training and certification.

The Service Center Certification is designed to ensure that a certified service representative has at their disposal the proper facilities necessary to complete quality repairs.

Only those facilities which are authorized Respironics Service Centers are sold replacement parts. For information on becoming an authorized service center contact Technical Services at 800/669-9234.

▼ Before returning a unit to the customer, include a new bacterial filter (p/n 7715) and the appropriate instruction sheet in the shipping box.

English	577-7700-10	Swedish	577-7700-40
German	577-7700-34	Dutch	577-7700-41
French	577-7700-31	Greek	577-7700-42
Italian	577-7700-36	Danish	577-7700-43
Spanish	577-7700-37	Finnish	577-7700-44

**Engineering
Change Orders**

**Authorized Service
Centers**

**Shipping New
Bacteria Filter**

Servicing Guidelines

▼ A unit passes Operational Checks if no discrepancy is discovered in unit operation other than; internal battery replacement, or other minor repairs or adjustments that do not require disassembly of the unit other than the top cover.

If the unit **is** being serviced due to a complaint, perform Operational Checks in Section 5.0 to find any other discrepancies with unit operation. The steps in Sections 6.0 through 10.0, including Preventive Service **MUST** also be performed, regardless of the number of hours remaining.

A unit automatically fails operational checks if any mandatory ECO is not installed.

Refer to the flow chart on the next page for a further description of servicing guidelines.

Introduction

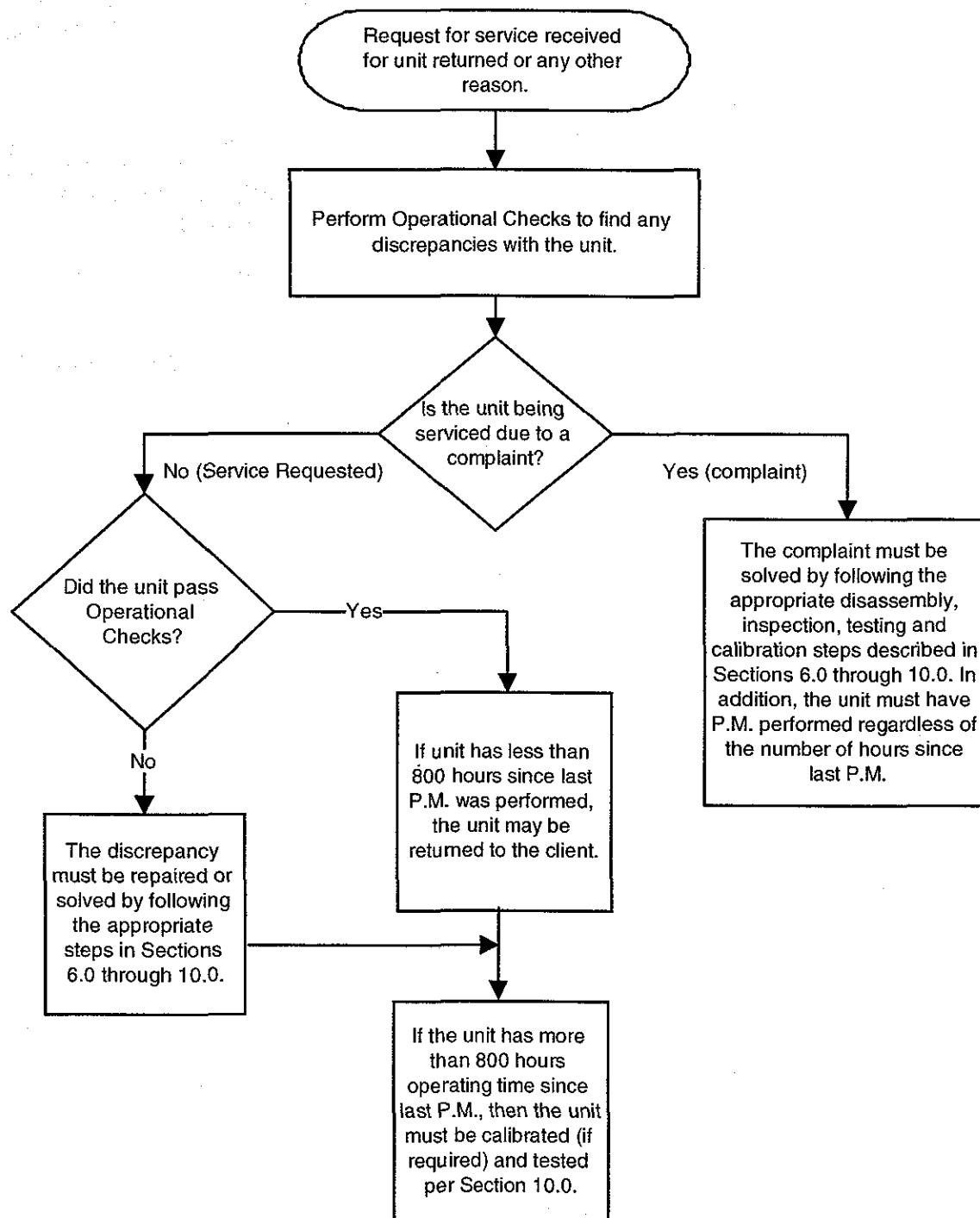
Servicing Guidelines
(Continued)

Figure 1: Servicing Guidelines

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Warnings and Cautions

Warnings and Cautions

Section 2.0

Warnings
Cautions
ESDS Warnings and Cautions

Warnings and Cautions

Warnings

- This is a non-continuous ventilator and is intended to augment patient breathing. It must not be used as a ventilator that supports or sustains life, and it is not intended to provide the total ventilatory requirements of the patient.
- Airflow generated by this device is limited to 150 liters per minute. The selection of certain combinations of settings (i.e., high rate and short risetime) may result in a situation where pressure support levels cannot be obtained.
- The use of a water trap and/or hydrophobic filter is recommended to prevent moisture from entering the ventilator.
- The use of bacteria filters are recommended to ensure client safety from cross contamination.
- DO NOT use the QUANTUM PSV in the presence of flammable anesthetics.
- Never operate this device if the power cord is damaged.
- Do not use this device if it has been dropped or damaged. Contact your dealer or Respironics immediately.
- Use only an identically rated and sized fuse for replacement.
- Oxygen vigorously accelerates combustion. Keep this device away from heat or open flame when using supplemental oxygen. This device must be running before turning on the supplemental oxygen. Turn off the oxygen before turning the device off. Do not smoke within 6 feet (2 meters) of this unit.
- Do not block any air intake vents.
- Do not kink or crimp air outlet hoses.
- Always unplug the Quantum PSV before cleaning the enclosure.
- Performance verification of the Quantum PSV must be performed before use.

Cautions

- The Quantum PSV must be periodically checked and maintained to ensure proper operation.
- Connect the Quantum PSV to a grounded hospital grade outlet only.
- Quantum PSV performance is affected at temperatures below 5°C and above 40°C.

SECTION 2.0

Warnings and Cautions

- Replace the back panel shipping fuse, as required, with a 3-amp 250V fast blow fuse, 5mm x 20mm.
- Positioning the Quantum PSV must not block the air intake ports located on the rear panel.
- Verify that the alarms are operational.
- Connect only Model 7703 Remote Control cables or other certified Sleep Recording Devices into the signal output part (SOP) of the Quantum PSV. Do not insert any devices into the signal input part (SIP) of the Quantum PSV.

Cautions (Continued)

- All ESDS items must be stored in approved conductive packaging, tubes, shipping bags, foam, or tote bins.
- All persons handling ESDS items must be grounded via a 1 Meg ohm resistive grounded wrist strap.
- Cover all ESDS bench tops with grounded conductive mats and connect all work surfaces and equipment to earth ground.
- Transport all assemblies containing ESDS items in a conductive bag or container.
- DO NOT use cellophane adhesive tape to wrap DIP (dual in-line package) tubes together.
- DO NOT handle ESDS items by their pins or mix them with other routine electronic parts.
- Never place ESDS items on ungrounded surfaces or leave them unattended in an open area.
- Avoid cellophane wrappers, synthetic carpeting, warm or cool air blasts, styrofoam coffee cups, etc. when working with ESDS items.
- Use only ESD safe solder suckers, grounded soldering irons, and grounded DIP installation tools.
- Use only properly designed heat lamps, heat chambers, and/or "antistatic" quick-chill sprays during troubleshooting or stress testing procedures.

ESDS Warnings and Cautions

Warnings and Cautions

**ESDS Warnings
and Cautions**

(Continued)

- The following assemblies in the Quantum PSV are easily damaged by ESD and require special handling:

Controller PCB
CPU PCB
Display PCB
Power Supply PCB
Sensor PCB
Encoder PCB

Specifications and Alerts

Specification and Alarms

Section 3.0

- Front Panel Controls
- Performance Specification
- Physical Specifications
- Power Requirements
- Output Signals
- Alerts
 - Front Panel Visual Indicators
 - Rear Panel Visual Indicators
 - Rear Panel
 - Power Alert
 - Patient Alert
 - System Alert

Specifications and Alerts

Front Panel Controls

- Power
On, Off
- Alert Status
Power Failure, Patient Leak, System Failure/Firmware Check Failure
- Pressure
cmH₂O
- **Mode Selection**
CPAP, Spontaneous, Spontaneous/Timed
- **Estimated Parameters**
Peak Flow, Minute Volume, Tidal Volume, Breath Rate
- **Patient Settings**
CPAP/EPAP, IPAP, Risetime, Rate, % I Time

Performance Specifications

- CPAP/EPAP Pressure Range
2 – 25 cmH₂O
- IPAP Range
2 – 30 cm H₂O, (Domestic)
2 – 35 cm H₂O, (35 cm H₂O Unit)
2 – 37 cm H₂O, (International Unit)
- Pressure Control Resolution
1 cmH₂O
- Pressure Accuracy
± 0.7 at zero flow
+ 0.0/ - 0.7 from zero flow measured at 150 LPM
- Pressure Response Time (Min)
0.1 seconds
(10 – 90% of pressure)
- Risetime Control Range
0.1 to 0.9 seconds in increments of 0.1 seconds
(10 – 90% of pressure)
- Rate Control Range
4 – 40 BPM
- Breath Rate Accuracy
± 1 BPM
- %I Time Control Range
10 – 90 % of total breath time

SECTION 3.0

Specifications and Alerts

- Flow Trigger

Inspiration	0.25 liters per second
Expiration	Peak Flow x.75
- %I Time Accuracy

± 1%	
Minimum Expiration Time	500 msec
Minimum Inspiration Time	200 msec
Maximum Inspiration Time	3 sec
- Flow Limit

150 LPM

Performance Specifications

(Continued)

- Height

8"	20.5 cm
----	---------
- Width

12.75"	31.9 cm
--------	---------
- Length

13"	32.6 cm
-----	---------
- Weight

15.73 lbs.	7.15 kg
16.7 lbs.	7.6 kg

Physical Specifications

- Voltages

100 – 120 VAC at 50/60 Hz
200 – 240 VAC at 50/60 Hz
- Current consumption

300VA

Power Requirements

- Operating Temperature

5° - 40° C

- Storage and Transport Conditions

Temperature	-20° - 60° C
Humidity	10% – 95% Non-condensing
Barometric Pressure	790 – 525 mmHg

Operating/Storage Requirements

Specifications and Alerts

Output Signals

- **Pressure**
 Range 0 – 4 volts
 Voltage 0.1 V = 1 cmH₂O

- **Flow**
 Range 0 – 4 volts
 Voltage 1.0 V = 60 LPM

Alerts

- **Power**
 Visual/Continuous Audible

- **Patient**
 Visual/Continuous Audible

- **System**
 Device Failure – Visual/Continuous Audible
 Firmware Check Failure – Intermittent Visual/Intermittent Audible

Front Panel Visual Indicators

- **Power**
 Green Indicator Light

- **Pressure cmH₂O**
 Green Digital Bar Graph

- **Power Alert**
 Red Indicator Light

- **Patient Alert**
 Yellow Indicator Light

- **System Alert**
 Red Indicator Light

- **CPAP Mode**
 Red Indicator Light

- **Spontaneous Mode**
 Green Indicator Light

- **Spontaneous/Timed Mode**
 Green Indicator Light

- **Peak Flow Estimation**
 Green Indicator Light/Digital Display

- **Minute Volume Estimation**
 Green Indicator Light/Digital Display

SECTION 3.0



Specifications and Alerts

- **Tidal Volume Estimation**
Green Indicator Light/Digital Display
- **Breath Rate Estimation**
Green Indicator Light/Digital Display
- **CPAP/EPAP Setting**
Digital Display
- **IPAP**
Digital Display
- **Risetime**
Digital Display
- **Rate**
Green Indicator Light/Digital Display
- **% I Time**
Digital Display

Front Panel Visual Indicators

(Continued)

- **Hour Meter**
Digital Display
- **AC On**
Green Indicator Light

Rear Panel Visual Indicators

- **Output Pressure**
Phone Type Jack
- **Estimated Flow**
Phone Type Jack
- **Serial Port**
RS-232 Port
- **Power Receptacle**
Three Wire AC Receptacle
- **Fuse**
3A, 250V
- **Fan**
24 VDC

Rear Panel

Specifications and Alerts

Power Alert

▼ The power alert sounds an audible and visual alert indicating when power to the device is lost when the power switch is in the on position. This alert also sounds when the device's fuse fails. This alert is silenced by either restoring power to the device or turning the power switch off.

Patient Alert

▼ The patient alert yellow light illuminates and the alert sounds indicating that the PSV flow rate exceeds the predicted flow rate by a preset amount for thirty seconds. The flow rate prediction is based on the bias flow rate for any given pressure. As the pressure rises so does the bias flow. The alert trigger level follows the bias flow level. Since the flow must exceed the alert trigger level for thirty seconds the alert indicates only large mask leaks or circuit disconnections. This alert is reset automatically once the flow rate returns to normal.

System Alert

▼ The system alert causes the red light to illuminate and a continuous alarm to sound indicating a device failure. A device failure results in pressure varying from the set pressure by plus or minus 5 cmH₂O for 0.5 seconds. When the device flow exceeds the flow limit (150 lpm) the system alert for low pressures does not occur. When the controls are locked out the system alarm causes the blower to stop. This alert is reset by turning the device off.

The system alert cause the red light to illuminate and an intermittent alarm to sound indicating an internal firmware check failure which occurs when the device is being reset. When this alarm continues for more than five minutes, consider the device to be non-function and requiring service.

Note: No audible alerts sound when the remote control is connected to the PSV.

Troubleshooting Chart

Section 4.0

Troubleshooting Chart

NOTE: The possible causes and actions/solutions listed below are used as guidelines for troubleshooting the Quantum PSV. This list is **NOT** complete and other possible causes and solutions should **NOT** be ruled out. Refer to the Theory of Operation and PCB schematics, as required, to further troubleshoot the Quantum PSV.

If there is a problem with a certain part of a circuit, check the continuity of all traces, and inspect for fractured solder joints.

Problem	Possible Cause	Action/Solution
1.0 System Alarm.	1.1 Pressure switch wire wrong	1.1 Check wiring on pressure switch.
	1.2 Over pressure safety switch out of tolerance	1.2 Replace over pressure safety switch
	1.3 Bad ribbon cable	1.3 Clean ribbon cable connectors with alcohol. If problem still persists, replace 16 pin ribbon cable.
	1.4 Valve Sticking.	1.4 Replace Valve.
	1.5 Defective controller board.	1.5 Replace controller board.
	1.6 Defective sensor PCB.	1.6 Replace sensor PCB.
2.0 Patient Alarm	2.1 Loose Hose.	2.1 Replace Hose.
	2.2 Out of Calibration.	2.2 Recalibrate Unit.
3.0 Low Flow and/or Pressure.	3.1 Sensor board or Controller board out of calibration.	3.1.1 Dirty filter or air intake.
		3.1.2 Sticking valve.
		3.1.3 Calibrate unit.
	3.2 Blower.	3.2 Replace Blower.
4.0 Hot air coming out of patient outlet.	4.1 Blower.	4.1 Replace Blower.
5.0 Unit over-heating.	5.1 Defective fan.	5.1 Replace fan.
6.0 Excessive noise and chattering.	6.1 Valve or Controller board	6.1 Clean Valve, or check board.
	6.2 Defective Blower	6.2 Replace Blower.
7.0 Hour meter not functioning.	7.1 Loose wiring.	7.1 Check wiring to controller board.
	7.2 Defective hour meter.	7.2 Replace hour meter.

SECTION 4.0



Troubleshooting Chart

Problem	Possible Cause	Action/Solution
8.0 Front panel display not functioning.	8.1 50-pin ribbon cable to CPU board.	8.1 Check 50-pin ribbon cable connection.
	8.2 Defective CPU board.	8.2 Replace CPU board.
	8.3 Main display board or Encoder board.	8.3 Replace Main board and Encoder board.
	8.4 Defective Power Supply	8.4 Replace Power Supply
9.0 Unit does not turn on, green A/C LED is not illuminated.	9.1 Power cord is not securely attached to the unit or wall outlet.	9.1 Check that the power cord is properly connect to the unit and wall outlet.
	9.2 Unit not connected to a live outlet.	9.2 Check that wall outlet has power.
	9.3 The fuse is blown.	9.3 Replace fuse with two 3A, 250V fuses.
	9.4 Check power switch.	9.4 Replace switch.
	9.5 Defective power board.	9.5 Check wiring harness going from controller board. Check 24 volts at red and black wires in middle of connector going to control board.
	9.6 Defective controller board.	9.6 Replace controller board.
	9.7 Defective AC inlet.	9.7 Replace AC inlet.
10.0 Unit does not turn on, green A/C LED illuminates	10.1 Relay failure.	10.1 Replace relay with FET module.
11.0 Unit does not turn off.	11.1 Defective relay on controller board.	11.1 Replace relay, (FET module ECO 6670 or ECO 6726).
	11.2 Defective power switch.	11.2 Replace power switch.
12.0 Incorrect pressure when measured by manometer.	12.1 Solenoid leak.	12.1 Tighten solenoid.
	12.2 Solenoid hose leak.	12.2 Replace hose.
	12.3 Unit out of calibration.	12.3 Calibrate unit.
	12.4 Defective valve.	12.4 Clean or replace valve.
	12.5 Blower leak.	12.5 Replace blower.

Troubleshooting Chart

Problem	Possible Cause	Action/Solution
12.0 Continued.	12.6 Defective blower.	12.6 Replace blower.
13.0 Pressure fluctuating during CPAP and IPAP.	13.1 Dirty filter or air intake.	13.1 Replace filter or air intake assembly.
	13.2 Pressure Sensor or Controller board out of calibration.	13.2 Calibrate unit.
	13.3 Valve sticking.	13.3 Clean or replace valve.

Operational Checks

Operational Checks

Section 5.0

Operational Checks
Using the RT-200, OR EQUIVALENT TEST EQUIPMENT
Visual Inspection
AC Line Indicator
Diagnostic Check
Panel Lock Check
CPAP/EPAP Control
IPAP Control
Low Pressure CPAP Performance Check
High Pressure CPAP Performance Check
BPM Control
%I Time Control
Bar Graph Display Check
Mode Selection Check
Pressure Verification
CPAP Pressure Check
IPAP Pressure Check
Spontaneous Mode Check
Spontaneous/Timed Mode Check
Approximate Timing Check
Power Alert Check
Patient Alert Check
System Alert Check
Estimated Parameters Check
Communication Port Check
Analog Pressure Output Check

Operational Checks

Operational Checks

▼ Operational Checks are used to find any discrepancies with the operation of the unit. If a unit fails any of these checks, other than a discrepancy requiring minor repairs the steps in Sections 6.0 through 10.0 MUST be performed.

A unit passes Operational Checks if no discrepancy is discovered in unit operation.

**Using an RT-200, OR
EQUIVALENT TEST
EQUIPMENT**

▼ A properly calibrated RT-200, OR EQUIVALENT TEST EQUIPMENT Calibration Analyzer may be used to perform Operational Checks, reassembly tests, unit testing, or calibration procedures as described in the Quantum Service Manual.

<u>Test Name</u>	<u>RT-200, Test No.</u>	<u>Readings / Scale</u>
CPAP Pressure Check	12	250cm H ₂ O
IPAP Pressure Check	12	250 cm H ₂ O
Pressure Verification	21	20 psi
Flow Measurements	36	180 lpm

Visual Inspection

▼ Inspect the unit case for scratches, dents, or other damage. Check that the case is securely fastened. Check that the fan, hour meter, and front panel knobs are secure and in good condition. Check that the displays are not scratched or damaged in any way.

AC Line Indicator

▼ Connect the AC power cord to the back of the unit. Plug the power cord into an AC outlet. The green AC LED on the rear panel illuminates indicating that the unit is in standby.

SECTION 5.0



Operational Checks

▼ Press the On/Off button to start the unit. The alert sounds and all alert displays illuminate briefly, followed immediately by illumination of all other LED displays. The green LED next to the On/Off button illuminates when the unit is operating. Adj is displayed on the Estimated Parameters window for 15 seconds. Check that the unit's cooling fan is operating.

▼ Lock the panel by pressing both of the Estimated Parameters buttons simultaneously until Loc appears in the display. Adjusting any of the system settings is not possible in the locked state. Unlock the panel by pressing both of the Estimated Parameters buttons simultaneously until Adj appears in the display.

▼ With the unit in CPAP mode, verify that the CPAP mode LED is illuminated.

Verify the CPAP/EPAP control range by setting the display from 2 cmH₂O to 25 cmH₂O.

Change the unit mode to Spont, and set the IPAP control to 30 cmH₂O. Verify the CPAP/EPAP control range by setting the display from 2 cmH₂O to 25 cmH₂O.

▼ With the unit in Spont mode, set the CPAP/EPAP control to 2 cmH₂O. Verify IPAP control range by setting the display to 2 cmH₂O, and to 30 cmH₂O (35 cmH₂O for 35 cm H₂O units, and 37 cm H₂O for International Units).

Set CPAP/EPAP to 10 cmH₂O. Slowly lower the IPAP range until it equals the CPAP/EPAP value. Verify that the CPAP mode indicator is flashing.

Continue to slowly lower the IPAP value. The CPAP/EPAP value must also decrease.

Diagnostic Check

Panel Lock Check

CPAP/EPAP Control

IPAP Control

Operational Checks

BPM Control

▼ Set the mode of the unit to Spont/Timed. The BPM displays the default value of 10. Verify the BPM control range by setting the display from 4 BPM to 40 BPM.

%I Time Control

▼ Set the mode of the unit to CPAP. Set the mode of the unit to Spont/Timed. The %I Time displays the default value of 33%. Verify the %I Time control range by setting the display from 10% to 90%.

Bar Graph Display Check

▼ The bar graph display must be within ± 1 cm H₂O to the digital CPAP/EPAP display in each of the control modes.

Mode Selection

▼ Press the Up and Down arrow keys under the Mode Select section. Occlude the outlet for CPAP and SPONT modes, and only partially occlude the outlet for SPONT/TIMED mode. The following LED's are illuminated during each mode:

CPAP CPAP LED illuminated

SPONT CPAP LED flashes
 SPONT LED illuminated

SPONT/TIMED SPONT/TIMED LED illuminated
 (CPAP LED flashes when CPAP/EPAP and IPAP
 settings are identical)

Set CPAP/EPAP to 2cm H₂O, then select the Spontaneous mode. Verify that the following system settings are displayed:

CPAP/EPAP	2 cm H ₂ O
IPAP	2 cm H ₂ O
Risetime	0.5 sec
Rate	Blank
%I Time	Blank

Select Spontaneous/Timed mode. Verify that the following system settings are displayed:

CPAP/EPAP	2 cm H ₂ O
IPAP	2 cm H ₂ O
Risetime	0.5 sec
Rate	10
%I Time	33

SECTION 5.0

Operational Checks

Set the system settings to the following:

IPAP	20 cm H ₂ O
CPAP/EPAP	10 cm H ₂ O
Risetime	0.3 sec
Rate	15
%I Time	40

Mode Selection

(Continued)

Turn off the unit and verify that all LEDs are blank. Wait thirty seconds and turn on the unit. Verify that the previous system settings are displayed.

Change the unit mode to Spontaneous and verify that the following system settings are displayed:

CPAP/EPAP	10 cm H ₂ O
IPAP	20 cm H ₂ O
Risetime	0.3 sec
Rate	Blank
%I Time	Blank

Set the unit mode to CPAP and verify that the following system settings are displayed:

CPAP/EPAP	10 cm H ₂ O
IPAP	Blank
Risetime	Blank
Rate	Blank
%I Time	Blank

Set the unit mode to Spontaneous/Timed and verify that the following system settings are displayed:

CPAP/EPAP	10 cm H ₂ O
IPAP	10 cm H ₂ O
Risetime	0.5 sec
Rate	10
%I Time	33

▼ Connect the restricted adapter (TS-7700-31) to the end of the Quantum's hose. Connect the 1/8" tubing on the flow restrictor to a pressure gauge, (see figure 2). Set the unit to the following system settings:

CPAP/EPAP	2 cm H ₂ O
IPAP	30 cm H ₂ O
Risetime	0.1 seconds
Rate	15 BPM
%I Time	50

Pressure Verification

Operational Checks
Pressure Verification

(Continued)

Verify that the low pressure is $2 \text{ cm H}_2\text{O} \pm 0.70 \text{ cm H}_2\text{O}$, and verify that the high pressure is $30 \text{ cm H}_2\text{O} \pm 0.70 \text{ cm H}_2\text{O}$.

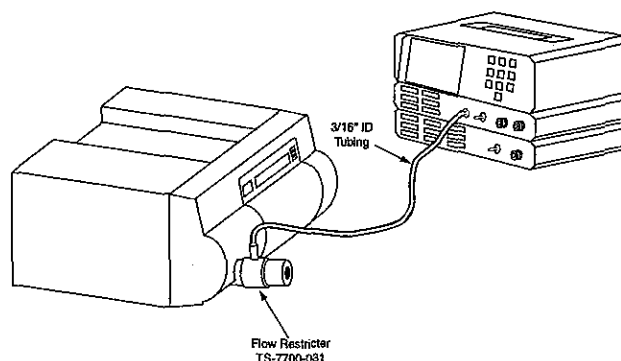


Figure 2: Set-up to Measure Pressure

CPAP Pressure Check

▼ Connect the flow restrictor to the end of the Quantum's hose. Connect the $\frac{1}{8}$ " tubing on the flow restrictor to a volume measuring device, (see figure 2).

Select the CPAP mode on the Quantum. Set the CPAP/EPAP knob until the display reads $25 \text{ cm H}_2\text{O}$. The RT-200, OR EQUIVALENT TEST EQUIPMENT must display a pressure of $25 \text{ cm H}_2\text{O} \pm 0.7 \text{ cm H}_2\text{O}$.

Set the CPAP pressure to $10 \text{ cm H}_2\text{O}$. Verify a pressure of $10 \text{ cm H}_2\text{O} \pm 0.7 \text{ cm H}_2\text{O}$.

Set the CPAP pressure to $2 \text{ cm H}_2\text{O}$. Verify a pressure of $2 \text{ cm H}_2\text{O} \pm 0.7 \text{ cm H}_2\text{O}$.

IPAP Pressure Check

▼ Connect the flow restrictor to the end of the Quantum's outlet. Connect the $\frac{1}{8}$ " tubing on the flow restrictor to a pressure measuring device.

Select the Spont/Timed mode on the Quantum. Set the Quantum parameters to the following:

CPAP/EPAP	$2 \text{ cm H}_2\text{O}$
IPAP	
Domestic Units	$30 \text{ cm H}_2\text{O}$
International Units	$37 \text{ cm H}_2\text{O}$
$35 \text{ cm H}_2\text{O}$ Units	$35 \text{ cm H}_2\text{O}$
Risetime	0.1 seconds
Rate	10 BPM
%I Time	50

SECTION 5.0

Operational Checks

Verify that the five breathing cycles take 30 seconds $\pm$ 1 second to complete.
 Verify that the forced breath LED, located to the left of the Rate display, illuminates during each breath.
 Reset the Michigan Lung to the following parameters:

Proximal Resistance	Rp5
Lung Resistance	Rp20
Lung Compliance	0.05

Verify that the five breathing cycles take 30 seconds $\pm$ 1 second to complete.
 Verify that the forced breath LED, located to the left of the Rate display, illuminates during each breath.

Spontaneous/Timed Mode Performance Check (Continued)

▼ Connect a flow restrictor to the Quantum's patient outlet. Set the unit to the following parameters:

CPAP/EPAP	5 cm H ₂ O
IPAP	15 cm H ₂ O
Risetime	0.1 seconds
Rate	10 BPM
%I Time	50

The unit defaults to the EPAP pressure, and the barograph displays 5 cm H₂O. After 3 seconds $\pm$ 0.5 seconds, the barograph increases to 15 cm H₂O for 3 seconds $\pm$ 0.5 seconds.

Set the Quantum to the following parameters:

CPAP/EPAP	5 cm H ₂ O
IPAP	15 cm H ₂ O
Risetime	0.1 seconds
Rate	5 BPM
%I Time	25

The unit defaults to the EPAP pressure, and the barograph displays 5 cm H₂O. After 9 seconds $\pm$ 0.5 seconds, the barograph increases to 15 cm H₂O for 3 seconds $\pm$ 0.5 seconds.

Set the Quantum to the following parameters:

CPAP/EPAP	5 cm H ₂ O
IPAP	15 cm H ₂ O
Risetime	0.1 seconds
Rate	20 BPM
%I Time	66

The unit defaults to the EPAP pressure, and the barograph displays 5 cm H₂O. After 1 second $\pm$ 0.5 seconds, the barograph increases to 15 cm H₂O for 2 seconds $\pm$ 0.5 seconds.

Approximate Timing Verification

Operational Checks

Power Alert Check

▼ With the unit running, unplug the AC power cord from its supply. The alarm must sound for at least five seconds, and the red Power LED must illuminate immediately. Plug the AC power cord back into its supply. The alarm must cease.

Patient Alert Check

▼ Connect a flow restricter(TS-7700-031) to the outlet port. Set the parameters to the following:

CPAP/EPAP	5 cm H ₂ O
IPAP	30 cm H ₂ O
Risetime	0.3 seconds
Rate	4 BPM
%I Time	50

Remove the flow restricter from the outlet port. The alert sounds within 30 seconds of removing the flow restrictor. The alert is silenced by replacing the flow restricter on the outlet port.

System Alert Check

▼ Set the Quantum to CPAP mode. Set the CPAP pressure to 20 cm H₂O. Connect a 10 cm H₂O positive pressure source (7300 or equivalent) to the outlet port of the unit. Block the exhalation port on the rear panel of the unit. The alert sounds, when the pressure exerted exceeds 5 cm H₂O for 0.5 seconds. To reset the alert, turn off the unit.

Estimated Parameters Check

▼ Set the unit mode to Spontaneous/Timed. Connect the Quantum to the Michigan Lung using a 22mm hose. Set the Michigan Lung to the following settings:

Proximal Resistance	Rp5
Lung Resistance	Rp20
Lung Compliance	0.05

Set the system settings to the following:

CPAP/EPAP	2 cm H ₂ O
IPAP	25 cm H ₂ O
Risetime	0.1 seconds
Rate	10 BPM
%I Time	25

Let the unit stabilize for one minute before reading displays. Verify that the unit displays the following estimated parameters:

Minute Vol	17.80 ± 5.34
Tidal Vol	1.780 ± 0.534
Rate	10

SECTION 5.0

Operational Checks

▼ Connect a 7703 Remote Unit to the rear panel of the Quantum Main Unit. Verify that adjusting the controls on the Remote Unit changes the displays on the Main Unit. Verify that the readings on the Main Unit match those displayed on the Remote Unit. Perform the Alert checks to verify that the Main Unit transmit alert signals to the Remote Unit.

Communication Port Check

▼ Using a mini-phono plug, connect the positive lead of a volt-meter to the tip of the phono plug, and the negative lead to the sleeve of the phono plug. Select the CPAP mode on the unit. Set the CPAP pressure to 15 cm H₂O.

Analog Pressure Output Check

Connect the unit to a pressure measuring device using a flow restrictor (TS-7700-031) and 3/16" tubing, (see figure 2). Verify that the unit pressure is 15.0 ± 0.7 cm H₂O on the pressure gauge.

Refer to the following formula to determine the voltage measure range measured at the above pressure:

$$\frac{\text{Pressure Measured (cm H}_2\text{O)}}{10} = \text{voltage} \pm 0.05 \text{ volts}$$

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Preventive Service

Preventive Service

Section 6.0

Preventive Service Procedures
Mandatory Engineering Change Orders (ECOs)
Quality Control Check-Out Procedures

**Preventive Service
Procedures**

▼ The following Preventive Service procedures MUST be followed each time a Quantum PSV is serviced.

Refer to Sections 4.0, 7.0, and 10.0 for detailed information on performing these procedures.

Perform the following procedures:

- Perform operational verification check and note any nonconformance (see Section 5.0)
- Check external inlet filter for cleanliness. Replace if dirty.
- Dual Impeller (new style) blower, (see Section 7.0):
 - Inspect Filter Air Intake Screen. If dirty, replace with a new screen (p/n 7719). Install a filter screen if one is not present.
 - If Inlet screen is dirty or non-existent, check blower inlet screen on the Air Inlet Baffle (p/n 600-07700-17) for cleanliness. If the screen is dirty, replace the Air Inlet Baffle according to the procedures in Section 7.0).
 - Check cleanliness of blower hoses, flow meter bypass, valve inlet hose, valve, and valve outlet hose. Replace as required
 - If screen was dirty, remove upper and lower blower housings. Clean motor impellers and inside of both housings.
- Single Impeller (old style) blower, (see Section 7.0):
 - Inspect foam seals to ensure proper seating between aluminum blower shells and no air leaks. Replace blower if leaks are detected.
 - Inspect external inlet filter backup screen. Replace filter if dirty.
 - Inspect blower hose, valve inlet hose, and valve outlet hose. Replace hoses as required.
- Clean valve per valve cleaning procedure, (see Section 7.0)
- Incorporated all mandatory ECO's, (see Section 8.0).
- Replace battery, (see Section 7.0)
- Recalibrate blower/sensor/valve sub-assembly per calibration procedure, (see Section 10.0)
- Troubleshoot and repair any nonconformance as appropriate, (see Section 4.0)

SECTION 6.0



Preventive Service

▼ Install all applicable ECOs including those listed below. Refer to Section 8.0, Engineering Change Orders, for detailed installation instructions.

ECO #5147	Controller Board Upgrade
ECO #5465	Valve Replacement
ECO #5557/5505	Hour Meter Installation for New Style Back Panels
ECO #5769	CPU Board Upgrade
ECO #5850	Valve Replacement
ECO #6065	Fuse Drawer
ECO #6726/6670	U31 Relay Replacement

Mandatory Engineering Change Orders (ECOs)

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Disassembly, Inspection, and Reassembly

Disassembly, Inspection and Reassembly

Section 7.0

Disassembly, Inspection, and Reassembly
Case Removal and Inspection
Intake Baffle Removal
Blower Assembly Removal
Fan Removal
Hour Meter Removal
AC Inlet Removal
Alarm Battery Replacement
Controller Board Removal
CPU Board Removal
Power Board Removal
Front Panel Removal
Front Panel Bracket Removal
Alarm Assembly Removal
Display Board Removal
Valve Removal
Sensor Board Removal
Pressure Switch Removal
Solenoid Removal
Old Style Auxiliary Valves
Noise
Final Unit Reassembly

Disassembly, Inspection, and Reassembly

**Disassembly,
Inspection, and
Reassembly**

▼ Follow the instructions below for disassembly, inspection, and reassembly of the Quantum PSV 7700. A list of service kits may be found in Section 11.0. These kits contain all the parts necessary to perform the specific replacements.

CAUTION: Observe all antistatic precautions before handling printed circuit boards. Refer to antistatic control procedure for information concerning the handling of static sensitive parts. All persons handling static sensitive parts must be grounded via a 1 Meg Ohm resistive grounded wrist strap.

**Case Removal and
Inspection**

▼ Using a phillips screwdriver, remove the seven screws from the edge of the back panel. Remove the phillips or hex head screw from underneath the handle. Remove the six phillips screws that secure the case to the bottom of the unit, (see figure). Carefully, remove the cover from the unit.

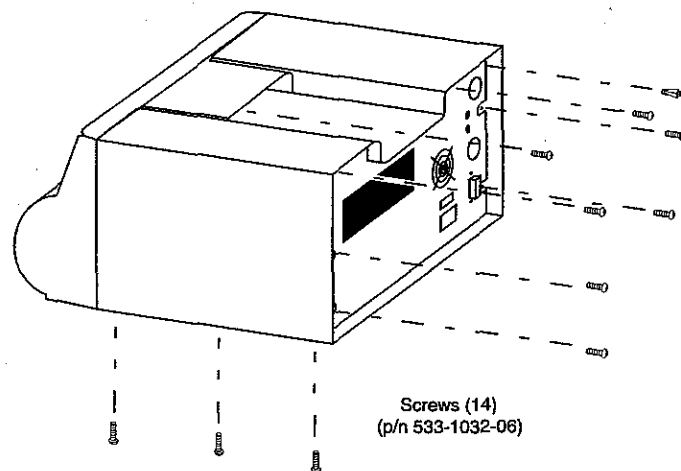


Figure 4: Screw Removal

Inspect inside the unit for wire, hosing, loose parts and assemblies, and other damage.

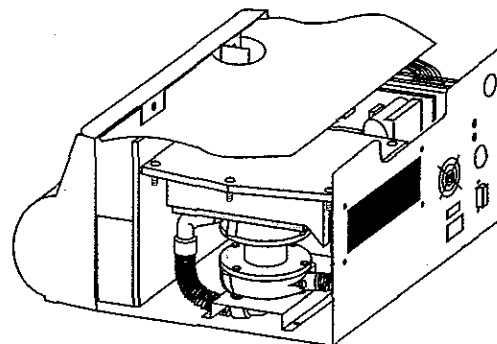


Figure 5: Case Removed

SECTION 7.0

Disassembly, Inspection, and Reassembly

▼ Using a phillips screwdriver, remove the four screws that secure the intake baffle to the rear panel of the unit. Inspect the Intake Baffle for case cracking or other damage. Replace as necessary.

Intake Baffle Removal

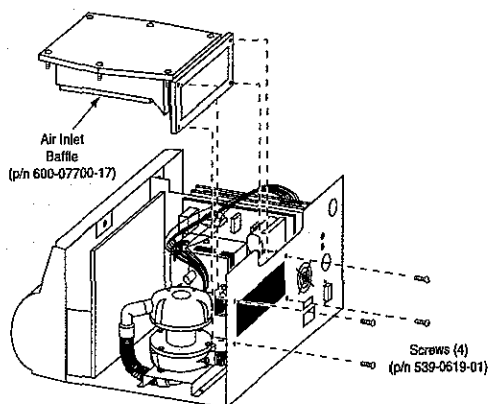


Figure 6: Intake Baffle Removal

▼ Using a phillips screwdriver, remove the screw from the bottom panel of the unit that secures the blower assembly in place. Remove the remaining three screws from inside the unit that secures the blower assembly bracket to the bottom panel.

Blower Assembly Removal

Disconnect the 8-pin connector from J7 of Controller Board. Disconnect the 1/16" ID pressure sensing line from exhaust port of the blower. Disconnect tubing from the pressure sensing port of the assembly. Remove the assembly from the unit.

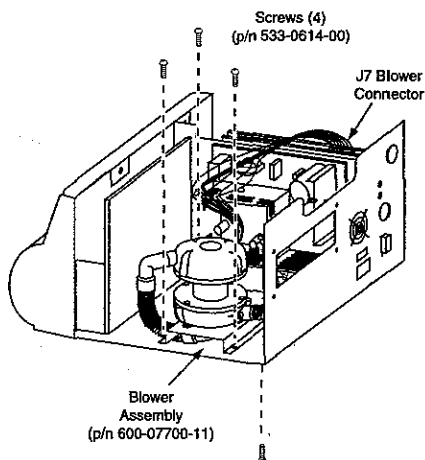


Figure 7: Blower Removal

Disassembly, Inspection, and Reassembly

Blower Assembly Removal

(Continued)

Using a phillips screwdriver, remove the three screws that secure the blower to the blower bracket. Remove the single screw that secures the pressure sensing port to the blower bracket. Remove the blower.

Check the three rubber grommets for wear, tears, or brittleness. Replace as necessary.

Single Impeller (Old Style) Blower Assembly Removal

Remove the screw that is located in the middle of each blower mount on the bottom of the unit. Disconnect the 8-pin connector from the J7 on the Controller board. Cut the cable tie at the upper front corner of the PCB bracket.

Disconnect the ground wire from the side of the blower box assembly. Disconnect the $\frac{1}{16}$ " ID clear tubing from the barb on the front side of the blower box. Disconnect the $\frac{1}{8}$ " ID Green and $\frac{1}{8}$ " ID Black tubing from the front side of the blower box.

Disconnect the 22mm clear tubing from the outlet port of the blower box. Remove the blower box from the unit.

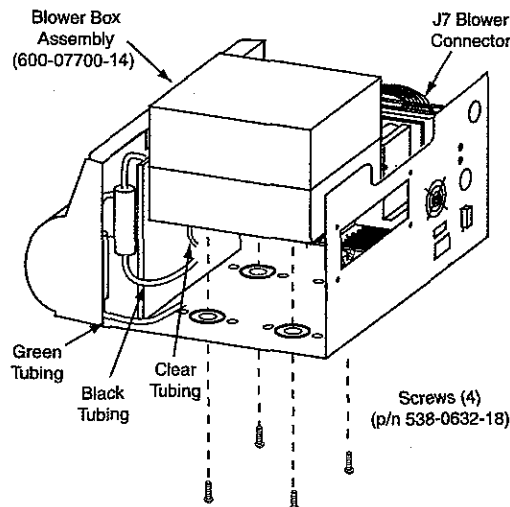


Figure 8: Single Impeller (Old Style) Blower Assembly Removal

Consult the following table to determine which blower to order according to the current Quantum hardware:

Controller Board	Sensor Board	Blower
630-07700-30	630-07700-40	600-07700-14
630-07700-50	630-07700-40	600-07700-14
630-07700-50/-51	630-07700-60	600-07700-13

SECTION 7.0



Disassembly, Inspection, and Reassembly

▼ Remove the three screws securing the blower assembly to the chassis. Disconnect the two hoses from the blower housings. Remove the top and bottom blower housings by removing the four screws that secure the blower housing to the motor/impeller assembly. Return the motor/impeller assembly to Respironics for repair. Do not attempt to repair the motor or remove the impeller blades. This may void the warranty.

Motor/Impeller Assembly Removal

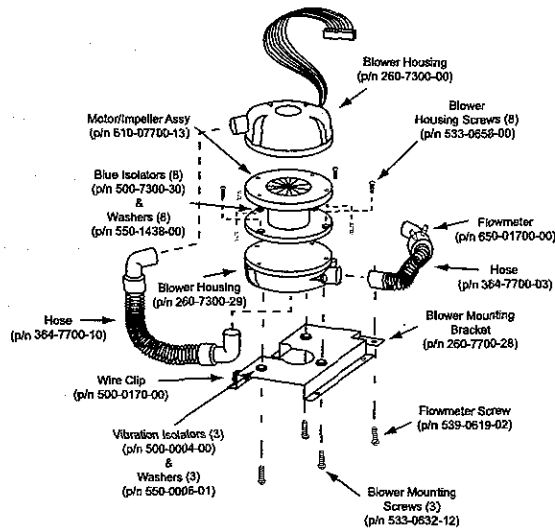


Figure 9: Motor/Impeller Assembly Removal

When reassembling the unit, the top blower housing is positioned 120° from the bottom blower assembly.

▼ Using a phillips screwdriver and 1/4" wrench, remove the four screws and nuts that secures the fan to the rear panel of the unit. Disconnect the fan's 2-pin cable at J1 of the Controller Board. Replace the fan as necessary.

Fan Removal

▼ Disconnect the hour meter 2-pin cable from J2 of Controller Board. Remove the hour meter from the rear panel of the unit by squeezing on the hour meter tabs and pushing the hour meter through the rear panel. Remove the power supply board first to aid in the hour meter removal. Replace as necessary.

Hour Meter Removal

▼ Disconnect the 5-pin, three wire (brown, blue, green) connector from J1 of the power board. Using a phillips screwdriver, remove the two screws that secure the power receptacle to the rear panel of the unit. Using a pair of pliers, remove the two female quick-disconnect terminals from the power receptacle. Note the orientation of the wires (blue – neutral, brown – live).

AC Inlet Removal

Using a 1/4" wrench, remove the nut that secures the grounding wire to the rear panel. Remove the power receptacle from the rear panel. Replace as necessary.

Disassembly, Inspection, and Reassembly

Alarm Battery Replacement

▼ Remove the battery from CPU Board by lifting the battery from the open end of the battery case. Replace battery as necessary. Align new battery according to terminals and snap in place on the board.

CPU Board Removal

▼ Remove the two stand-offs located on either side of the "D"-Type connector on the rear panel. Disconnect the 50-pin ribbon cable from P1 by lifting up on the end levers of the connector. Remove the four screws that secure CPU board in place. Gently disengage the CPU board from the Controller board at P2. Replace CPU board as necessary.

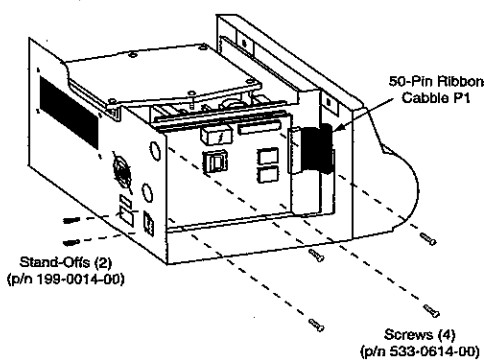


Figure 10: CPU Board Removal

Controller Board Removal

▼ Disconnect the Hour Meter cable from J1. Disconnect the fan cable from J2. Disconnect the 8-pin blower cable from J7. Disconnect the power supply board 8-pin connector from J6. Disconnect the two 2-pin valve cables from J5. Disconnect the 2-pin alarm connector from J3. Disconnect the 15-pin sensor board cable from J4 by lifting up on the end levers of the connector.

Using a 1/4" nut driver, remove the four stand-offs that secure the Controller board to the PCB bracket of the unit. Replace as necessary.

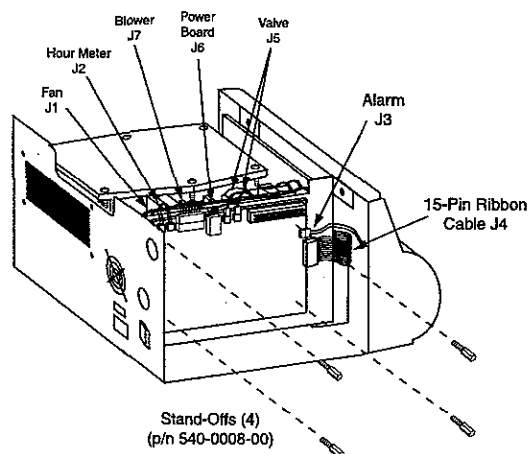


Figure 11: Controller Board Removal

SECTION 7.0



Disassembly, Inspection, and Reassembly

▼ Disconnect the 5-pin 3-wire (brown, blue, green) power cable from J1 of power supply board. Disconnect the 8-Pin CPU board power cable from J6. Using a phillips screwdriver, remove the four screws that secure power supply board to the PCB bracket. Note, removing the Valve bracket first aids in power supply board removal.

Power Supply Board Removal

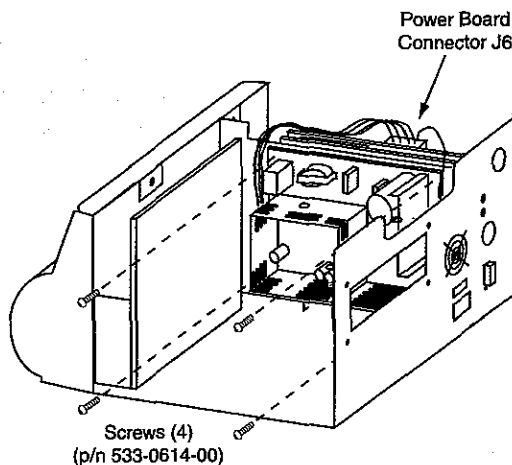


Figure 12: Power Supply Board Removal

▼ Using a phillips screwdriver, remove the three screws from bottom of the front panel. Remove the screw that secures the PCB bracket to the front panel. Disconnect the alarm cable from J3 on Controller board. Disconnect the 50-pin ribbon cable from P1 on controller board by lifting up on the end levers of the connector. Disconnect the 90° piece of flex tubing from the output port to the valve.

Front Panel Removal

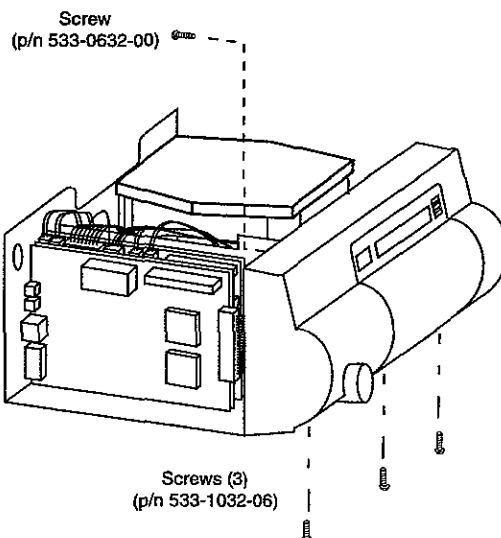


Figure 13: Front Panel Removal

Disassembly, Inspection, and Reassembly

Front Panel Bracket Removal

▼ Using a phillips screwdriver, remove the three screws along the bottom edge of the front panel bracket. Remove the three screws along the top edge of the front panel bracket. Remove the sound dampening assembly from the top edge of the front panel bracket. Remove the front panel bracket from the front panel.

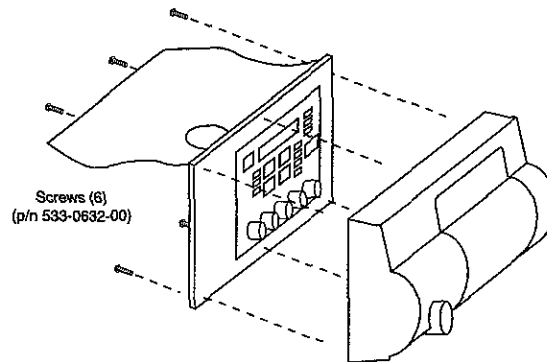


Figure 14: Front Bracket Removal

Alarm Assembly Removal

▼ Unscrew the alarm retaining ring from the front side of the front panel. Remove the alarm assembly from the front panel. Replace as necessary.

Display Board Removal

▼ Using a small allen wrench (0.050"), loosen the set screws on the five control knobs. Remove the knobs. Using a phillips screwdriver, remove the four screws securing main display board to the front panel bracket. Replace as necessary.

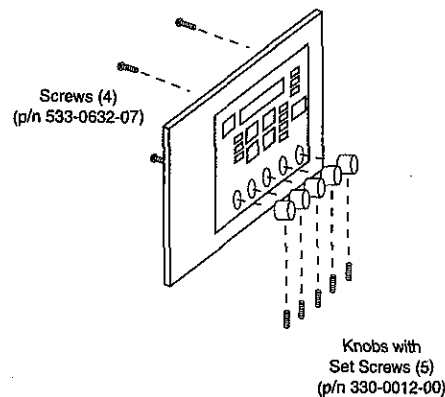


Figure 15: Display Board Removal

Disassembly, Inspection, and Reassembly

▼ Using a phillips screwdriver, remove the screw from the bottom panel that secures the Valve in place. Remove the remaining screw located under the power board that secures the Valve to the bottom panel. Cut the cable tie that secures the Valve to the Valve Bracket Assembly.

Disconnect the red tubing from the yellow end of the small solenoid valve. Disconnect the 2-pin pressure transducer cable from J4, (J2 on older units), on the sensor board. Disconnect the two 2-pin valve connectors from J5 on the Encoder Board. Disconnect the 22mm blower tubing from the side of the Valve. Disconnect the 22mm vent tubing from the top of the Valve.

Remove the valve from the unit.

Valve Removal

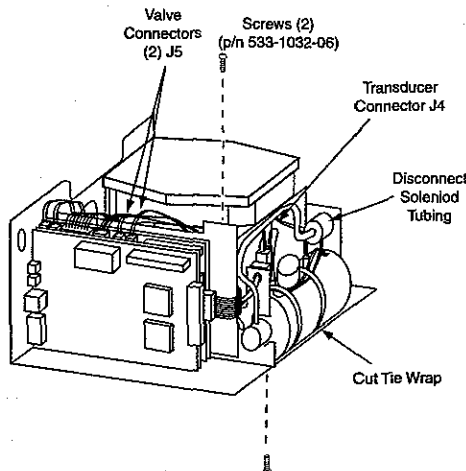


Figure 16: Valve Removal

Consult the following table to determine which valve to order according to the current Quantum hardware:

Controller Board	Sensor Board	Valve
630-07700-30	630-07700-40	600-07700-06
630-07700-50	630-07700-40	600-07700-07
630-07700-51	630-07700-60	600-07700-07

Disassembly, Inspection, and Reassembly

Valve Cleaning

▼ The following procedure is used to clean both the -06 and -07 valves.

Required Equipment:

Two stainless steel basins
White Vinegar
Isopropyl alcohol (p/n 200-4662-00)
High pressure clean dry air
Torque control screwdriver

Required Materials:

Valve Rebuilding kit (p/n 7782 for -06 valves and p/n 7783 for -07 valves).

P/N	Description	Quantity
538-0632-08	Screw	4
538-1032-10	Hex Screw	4
551-0006-00	Washer	4
551-0010-00	Washer	4
500-7700-32	Inlet Gasket	1
500-7700-33	Outlet Gasket	1
364-1814-01	Red Tubing	1
364-1814-03	Blue Tubing	1
361-0001-14	Straight Barb	1
361-0001-18	Right Angle Barb	1
500-0078-10	Tie Wraps	2
500-7700-28	Foam (for -06 Valves only)	1

Valve Disassembly:

Cut both tie wraps that secure the valve in place. Remove the two screws (p/n 538-0632-08) and the two washers (p/n 551-0006-00) that secure the overpressure switch bracket to the manifold. Remove the bracket/switch assembly from the manifold. Remove the two remaining screws and washers from the valve manifold. Remove the manifold.

Discard both gaskets located on the valve housing. Remove the four hex screws and washers on the opposite end of the valve and remove the coil bobbin. Carefully slide the piston assembly, including magnet, out of the valve housing. Remove the magnet from the piston assembly and place in a clean container. Remove the two screws and washers from inside the piston. Place the linear actuator and linear rod in separate clean container.

Discard all hardware, red and blue tubing, and both barbs found on the manifold.

Valve Cleaning:

Fill one stainless steel basin with white vinegar and the other with alcohol. Fill the basins with enough liquid to cover all the parts. Place the valve housing and manifold in the vinegar for 20 minutes and the piston assembly for 10 minutes. Dry with a high pressure air source, then place the parts in the alcohol for 20 minutes, and the piston for 10 minutes. Again, dry with a high pressure air source.

Disassembly, Inspection, and Reassembly

Valve Reassembly:

Remove the protective adhesive backing from the inlet and outlet gasket and adhere to the valve housing, (see figure 17). Reconnect the linear actuator to the piston using two screws (p/n 538-0632-20) and washers (p/n 551-0006-40) inside the piston. Slide a 1 inch piece of 3/8" diameter heat shrink tubing (p/n 79-0009-30) over the piston post and linear actuator wires allowing 3/4" clearance above the body of the piston. Secure the tubing in place with a heat gun. Slide the valve piston assembly into the open end of the valve housing. Insert the magnetic portion of the actuator around the linear rod and inside the valve housing.

Secure the coil/bobbin onto this assembly using the four hex screws (p/n 538-1032-10) and washers (p/n 551-0010-00). Install the screws in the following manner: Place the washers on the screws and insert the screws into the holes of the coil/bobbin. Cross Tighten the screws to a torque of 8.0 inch pounds $\pm$ 2.0 inch pounds.

For a -06 Valve, remove the protective adhesive sheet from the foam, and adhere to the assembly, (see figure 17)

Insert the fitting (p/n 361-0001-14) into the assembly. Check that the fitting is positioned approximately parallel to the manifold surface. Connect one end of the red tubing to this fitting.

Secure the overpressure switch assembly to the manifold using the remaining screws and washers. Tighten the screws to a torque of 8.0 inch pounds $\pm$ 2.0 inch pounds. Insert the fitting (p/n 361-0001-18) into the assembly. Connect one end of the blue tubing to the fitting and the other end to the over pressure switch.

Valve Cleaning (Continued)

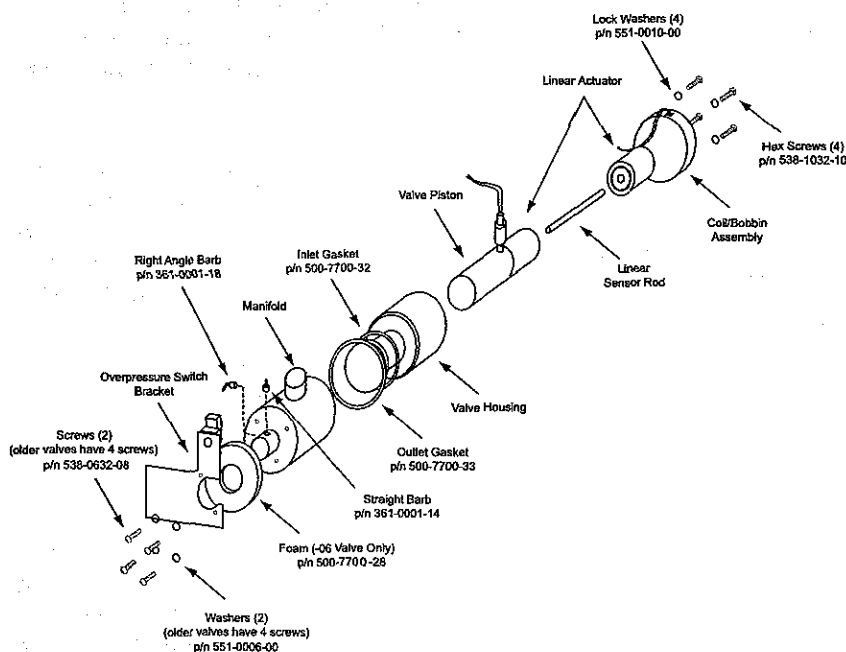


Figure 17: Valve Disassembly

Disassembly, Inspection, and Reassembly

Sensor Board Removal

▼ Remove the Valve as previously described. Disconnect the 15-pin ribbon cable from J1 on the sensor board by lifting up on the end levers of the connector. Disconnect the solenoid 2-pin cable from J2. Carefully disconnect the $\frac{1}{16}$ " clear tubing from the PT1 Transducer located on the sensor board. Disconnect the $\frac{1}{16}$ " red tubing from PT2. Disconnect the two pieces of $\frac{3}{16}$ " clear tubing from ports P1 and P2 of the U14 Pressure Transducer located on the sensor board. Remove the two screws securing the solenoid to the Valve Bracket. Remove the four screws that secure the board to the unit.

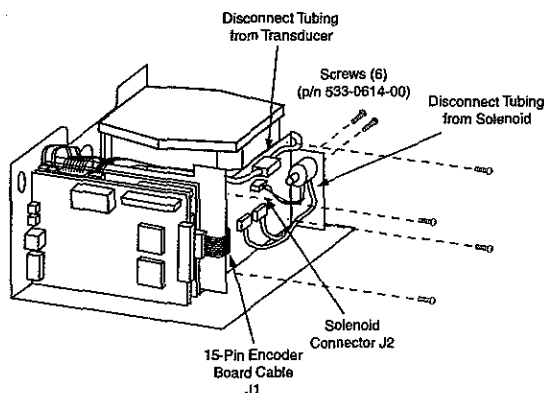


Figure 18: Sensor Board Removal

Old Style Sensor Board (-40)

To remove the old style sensor board, disconnect the 15-pin ribbon cable from J1 on the sensor board by lifting up on the end levers of the connector. Disconnect the three 2-pin connectors from J2. The top 2-pin connector at J2 is from the proportional valve, (first position on the header). The middle 2-pin connector at J2 is from the bottom solenoid valve, (third position on the header). The bottom 2-pin connector at J2 is from the top solenoid valve, (fifth position on the header).

Carefully disconnect the $\frac{1}{16}$ " ID black tubing and the $\frac{1}{16}$ " ID yellow tubing from the pressure transducer, PT3, on the sensor board. Disconnect the $\frac{1}{16}$ " ID Red tubing from the pressure transducer, PT2, on the sensor board. Disconnect the $\frac{1}{16}$ " ID clear tubing from the pressure transducer, PT1, on the sensor board.

Remove the four screws that secure the old style sensor board to the valve bracket.

SECTION 7.0

Disassembly, Inspection, and Reassembly

▼ Disconnect the blue tubing from the pressure switch. Disconnect the yellow 2-pin cable from J4, (or J2 on older units), on sensor board. Using a 1/4" nut driver, remove the two nylon locking nuts from the valve plate. Replace as necessary.

Pressure Switch Removal

▼ Disconnect the 2-pin cable from J2 of the sensor board. Using a phillips screwdriver, remove the two screws that secure the valve to the valve bracket. Disconnect the 1/8" valve red tubing from the top of the valve. Disconnect the 1/8" sensing red tubing from the out vent of the valve. Replace the valve as necessary.

Solenoid Removal

The old style sensor boards have two solenoid valves. To remove the second, lower, valve disconnect the 1/8" ID Green tubing from the top of the valve. Disconnect the 1/8" ID Black tubing from the IN port of the valve. Disconnect the 1/16" ID Yellow tubing from the OUT port of the valve. Disconnect the 2-pin cable from J2 of the sensor board. Remove the two screws that secure the valve to the valve bracket.

▼ Noise can be attributed to any number of factors including: valve vibration or flutter, air leaks in the sheet metal or foam of the blower enclosure, or motor failure. Isolate where the noise is coming from, and either replace that assembly or the foam that encloses the blower enclosure.

Noise

▼ Unit reassembly is in the reverse order of disassembly. Check that all pneumatic tubing is in position, and is not kinked. Check that all wiring is properly connected, and not pinched or strained by any of the unit's components. Check that all assemblies are securely fastened in place. Check that no parts or hardware were inadvertently left out. Then place the cover on the unit and secure in place with the screws previously removed.

Final Unit Reassembly

Disassembly, Inspection, and Reassembly

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ECO Changes

ECO Changes

Section 8.0

Mandatory Engineering Change Orders

ECO #: 6726/6670 U31 Relay Replacement

ECO #: 6065 Fuse Drawer Change Out

ECO #: 5850 Valve Replacement

ECO #: 5769 CPU Board Upgrade

ECO #: 5557/5505 Hour Meter installation for New Style Back Panels

ECO #: 5465 Valve Replacement

ECO #: 5147 Controller Board Upgrade

ECO Changes

Mandatory Engineering Change Orders

▼ Each Quantum PSV must have the following engineering change orders installed. The changes listed below are all mandatory changes.

If a unit does not have all of these changes installed, install them at the time of service. Record all installed ECO's on the proper documentation.

ECO#	Description
6726/6670	U31 Relay Replacement
6065	Fuse Drawer Change Out
5850	Valve Replacement
5769	CPU Board Upgrade
5557/5505	Hour Meter Installation for New Style Back Panels
5465	Valve Replacement
5147	Controller Board Upgrade

**ECO: 6726/6670
U31 Relay Replacement**

▼ This ECO replaces the relay module, U31, located on the Controller board.

CAUTION: Observe all antistatic precautions before handling printed circuit boards. Refer to antistatic control procedure for information concerning the handling of static sensitive parts. All persons handling static sensitive parts must be grounded via a 1 Meg Ohm resistive grounded wrist strap.

Remove the CPU board, and Controller board from the unit according to the instructions in Section 7.0 of this manual.

Place the Controller board on an ESD work station. U31 is located between the power plug and R136 pot on the controller board. Desolder and remove the relay from the Controller board. Discard the relay.

Install the new relay module into the footprint of the relay, U31, and solder the module to the board.

Install the Controller board, as well as the CPU board, into the unit.

Perform Calibration and Testing, (see Section 10.0). Reassemble the unit, and perform Run-In, (see Section 9.0).

ECO: 6065 Fuse Drawer Change Out

▼ This ECO replaces the old single fuse drawer with the newer dual fuse drawers. If a unit has an old single fuse drawer order Fuse Kit p/n 7791.

SECTION 8.0



ECO Changes

▼ Inspect the current valve for drain holes. There should be two drain holes in the valve housing, and one drain hole in the valve manifold. If these drain holes are not present, replace the valve with a new or refurbished valve (p/n 600-07700-06).

ECO: 5850 Valve Replacement

▼ Upgrade old CPU (p/n 630-07700-20) boards of revision A6 or earlier to the newest revision. Replace old style CPU boards using the procedures in Section 7.0 of this manual.

ECO: 5769 CPU Board Upgrade

▼ When replacing an old revision back panel with a newer revision back panel, install an hour meter (p/n 610-07700-25) in the unit.

**ECO: 5557/5505
Hour Meter Installation
for New Style Back
Panels**

Add a two pin header to the Control board (600-07700-30). Install shunt jumpers as follows:

P1 3 - 4

P2 1 - 2

P3 3 - 4

Cut the trace where between R199 and J1 above J7. Add jumper wire on solder side of board between J1 Pin 2 and J2 Pin 2.

▼ Check the valve housing. Replace the valve if it has a shiny, non-anodized aluminum exterior. Replace with a new or refurbished valve (p/n 600-07700-06) with a black, anodized housing. Replace per procedures found in Section 7.0 of this manual.

**ECO: 5465
Valve Replacement**

▼ Upgrade Controller boards (630-0700-30) at revision A2 or earlier to a 630-07700-50 Controller board. This also requires upgrading the valve from a 600-07700-06 to a 600-07700-07.

**ECO: 5147 Controller
Board Upgrade**

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Run-In

Run-In

Section 9.0

Run-In Requirements
Guidelines

Run-In Requirements

▼ Connect a one liter test lung to a restrictor (90037) to the outlet port of the unit. Set the Quantum parameters to the following:

CPAP/EPAP	2 cm H ₂ O
IPAP	30 cm H ₂ O
Risetime	0.1 seconds
Rate	15 BPM
%I Time	50 %

Verify that the pressure varies between 2 cm H₂O and 30 cm H₂O.

Relay Replacement

Let the unit run-in for a minimum of one hour. Perform Calibration and Testing (Section 10.0) at the completion of the run-in period.

Valve or Blower Replacement

Let the unit run-in for a minimum of 48 hours. Perform Calibration and Testing (Section 10.0) at the completion of the run-in period.

All Other Service

Let the unit run-in for a minimum of eight hours. Perform Calibration and Testing (Section 10.0) at the completion of the run-in period.

No Problem Found

If no problem was found with the Quantum PSV, operate the unit at the parameters at which the customer reported the problem. It may be necessary to operate these units for an extended period of time in order to diagnose an exhibited failure.

Guidelines

▼ If more than one category applies, the longest applicable run-in time is required. If service does not apply to any of the above categories, no run-in time is required.

If the run-in is stopped for repair, the stop run-in time and date are recorded, the necessary repairs made, and the run-in is restarted from zero hours and documented.

Run-in times listed are normal minimum times. There is no maximum run-in time.

Perform the Quality Control Final Inspection as applicable following any Preventive Service, General Service, or repair of a device or an accessory.

Calibration and Testing

Calibration and Testing

Section 10.0

- Calibration
 - Blower/Valve/Sensor Board Calibration
 - Controller Board Calibration
- AC Line Indicator
- Diagnostic Check
- Mode Selection Check
- Pressure Verification
- CPAP Pressure Check
- IPAP Pressure Check
- Spontaneous Mode Check
- Spontaneous/Timed Mode Check
- Approximate Timing Check
- Power Alert Check
- Patient Alert Check
- System Alert Check
- Estimated Parameters Check
- Communication Port Check
- Analog Pressure Output Check

Calibration and Testing**Calibration**

▼ Before calibrating the Quantum PSV, check the performance of the device to determine if it is necessary to calibrate the device. If a valve, blower, or the Controller Board has been replaced in the unit during service, calibration is required.

Every effort is made at Respironics during the manufacture of the Quantum PSV to ensure that the performance of the device is well within stringent specifications set by the Respironics Quality Control Program. However, if it is determined by the user that it is necessary to re-calibrate the device, proceed using the following procedures.

Sensor Board Calibration

▼ The following procedure is used to calibrate the blower assembly. Perform this procedure if the blower, valve, or sensor board was replaced during servicing.

Disconnect the AC power cord from the unit. Connect the ground lead of a volt meter to pin 5 or J1 on the sensor board. Connect the red lead to U12 pin 7 on the sensor board.

Connect the AC power cord to the unit. Disconnect the clear tubing from the PT1 pressure transducer on the sensor PCB. Turn on the unit and allow it to warm up for at least two minutes.

Adjust R67 on the sensor PCB to 0.000 ± 0.20 VDC according to the volt meter. Adjust R66 on the sensor PCB to 0.000 ± 0.002 VDC according to the volt meter.

Connect a pressure source to the low pressure range P+ port of the RT-200, OR EQUIVALENT TEST EQUIPMENT and tee off to PT1 on the sensor PCB. Adjust the pressure of the source until 40.00 cm H₂O is displayed on the RT-200, OR EQUIVALENT TEST EQUIPMENT. Adjust R68 on the sensor PCB to 4.000 ± 0.004 VDC according to the volt meter.

Note: Voltage may drift, but the drift must not exceed ± 0.014 VDC.

Remove the pressure tubing from the PT1 pressure transducer on the sensor PCB. Reconnect the clear tubing to PT1. Turn off the unit.

Connect the red lead of the voltmeter to U10 pin 8. Install a jumper across J2 pins 1 and 2 on the sensor PCB. Disconnect the red tubing from the valve pressure outlet, and connect a tee to the red tubing. Run one end to the low pressure range, P+, port of the RT-200, OR EQUIVALENT TEST EQUIPMENT and the other end to the pressure source. Zero the RT-200, OR EQUIVALENT TEST EQUIPMENT.

Turn on the unit, and set the pressure source for 37 cm H₂O as displayed by the RT-200, OR EQUIVALENT TEST EQUIPMENT. Adjust R64 to 3.7 ± 0.1 VDC as displayed by the volt meter. Remove the jumper from P2 and check that the reading does not change, (the reading is displayed every other cycle of the clippard solenoid). Turn off the unit.

SECTION 10.0



Calibration and Testing

Dual Impeller (New Style) Blower and Sensor PCB (-60)

Remove the air intake filter from the unit to gain access to the flow meter located behind the blower. Removed the hose from the blower outlet and connect it to the flow source (7300 CPAP or equivalent) with a gate valve in line. Disconnect the 22mm hose from the exhaust port of the valve. Using a hose adapter (p/n 260-7300-80) connect a 22mm hose from the exhaust port of the valve to the high flow range port on the RT-200, OR EQUIVALENT TEST EQUIPMENT, (see figure 19).

Blower/Valve/Sensor Board Calibration (Continued)

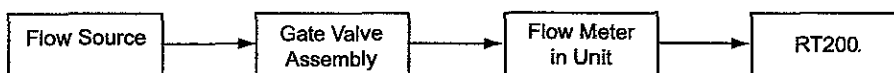


Figure 19: New Blower (-11) and Sensor PCB (-60) Calibration Setup Schematic

Close the gate valve, and zero the RT-200, OR EQUIVALENT TEST EQUIPMENT. Connect the red lead of the volt meter to U11 pin 8 on the sensor PCB. Turn on the unit and the flow source. Adjust the gate valve until the RT-200, OR EQUIVALENT TEST EQUIPMENT displays a flow of $90 \text{ LPM} \pm 1 \text{ LPM}$. Let the unit acclimate for twenty seconds and then adjust R69 to $1.50 \pm 0.05 \text{ VDC}$. Wait for 20 seconds, and then verify the adjustment remains at $1.50 \pm 0.05 \text{ volts}$. Turn off the unit and flow source.

Single Impeller (Old Style) Blower and Sensor PCB (-40)

Disconnect the output of the blower box and connect it to the 22mm hose from the gate valve. Completely close the gate valve, and connect the other end of the gate valve to the highflow range input on the RT-200, OR EQUIVALENT TEST EQUIPMENT, (see figure 20).

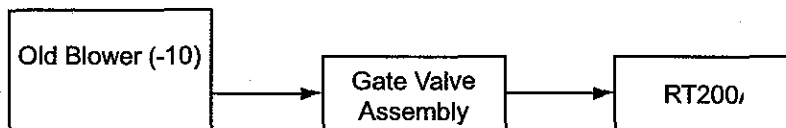


Figure 20: Old Blower (-10) and Sensor PCB (-40) Calibration Setup Schematic

Connect the red lead of the volt meter to U11 pin-8 on the sensor PCB. Turn on the unit power and zero the RT-200, OR EQUIVALENT TEST EQUIPMENT. Open the gate valve until 150LPM is displayed on the RT-200, OR EQUIVALENT TEST EQUIPMENT. Adjust R69 to a voltage of $2.50 \pm 0.05 \text{ VDC}$. Wait for 20 seconds, and then verify the adjustment remains at $2.50 \pm 0.05 \text{ VDC}$.

Calibration and Testing

Controller Board Calibration

▼ The following procedure is used to calibrate the controller board. Perform this procedure if any PCB was replaced during servicing.

Set the unit into CPAP mode. Adjust the CPAP/EPAP to 25 cm H₂O. Connect a flow restrictor (TS-7700-031) to the unit. Connect the 1/8" tubing to the P+ port of an RT-200, OR EQUIVALENT TEST EQUIPMENT. Adjust R136 on the controller board until the pressure is 25.00cm H₂O ± 0.70cm H₂O.

AC Line Indicator

▼ Connect the AC power cord to the back of the unit. Plug the power cord into an AC outlet. The green AC LED on the rear panel illuminates indicating that the unit is in standby.

Diagnostic Check

▼ Press the On/Off button to start the unit. The alert sounds and all alert displays illuminate briefly, followed immediately by illumination of all other LED displays. The green LED next to the On/Off button illuminates when the unit is operating. Adj is displayed on the Estimated Parameters window for 15 seconds. Check that the unit's cooling fan is operating.

Mode Selection

▼ Press the Up and Down arrow keys under the Mode Select section. Occlude the outlet for CPAP and SPONT modes, and only partially occlude the outlet for SPONT/TIMED mode. The following LED's are illuminated during each mode:

CPAP CPAP LED illuminated

SPONT CPAP LED flashes
 SPONT LED illuminated

SPONT/TIMED SPONT/TIMED LED illuminated
 (CPAP LED flashes when CPAP/EPAP and IPAP
 settings are identical)

Set CPAP/EPAP to 2 cm H₂O, then select the Spontaneous mode. Verify that the following system settings are displayed:

CPAP/EPAP	2 cm H ₂ O
IPAP	2 cm H ₂ O
Risetime	0.5 sec
Rate	Blank
%I Time	Blank

SECTION 10.0

Calibration and Testing

Select Spontaneous/Timed mode. Verify that the following system settings are displayed:

Mode Selection (Continued)

CPAP/EPAP	2 cm H ₂ O
IPAP	2 cm H ₂ O
Risetime	0.5 sec
Rate	10
%I Time	33

Set the system settings to the following:

IPAP	20 cm H ₂ O
CPAP/EPAP	10 cm H ₂ O
Risetime	0.3 sec
Rate	15
%I Time	40

Turn off the unit and verify that all LEDs are blank. Wait thirty seconds and turn on the unit. Verify that the previous system settings are displayed.

Change the unit mode to Spontaneous and verify that the following system settings are displayed:

CPAP/EPAP	10 cm H ₂ O
IPAP	20 cm H ₂ O
Risetime	0.3 sec
Rate	Blank
%I Time	Blank

Set the unit mode to CPAP and verify that the following system settings are displayed:

CPAP/EPAP	10 cm H ₂ O
IPAP	Blank
Risetime	Blank
Rate	Blank
%I Time	Blank

Set the unit mode to Spontaneous/Timed and verify that the following system settings are displayed:

CPAP/EPAP	10 cm H ₂ O
IPAP	10 cm H ₂ O
Risetime	0.5 sec
Rate	10
%I Time	33

Calibration and Testing

Pressure Verification

▼ Connect the flow restrictor (TS-7700-031) to the end of the Quantum's hose. Connect the 1/8" tubing on the flow restrictor to a pressure gauge, (see figure 2). Set the unit to the following system settings:

CPAP/EPAP	2 cm H ₂ O
IPAP	30 cm H ₂ O
Risetime	0.1 seconds
Rate	15 BPM
%I Time	50

Verify that the low pressure is 2 cm H₂O $\pm$ 0.70 cm H₂O, and verify that they high pressure is 30 cm H₂O $\pm$ 0.70 cm H₂O.

CPAP Pressure Check

▼ Connect the flow restrictor to the end of the Quantum's hose. Connect the 1/8" tubing on the flow restrictor to a volume measuring device, (see figure 2).

Select the CPAP mode on the Quantum. Set the CPAP/EPAP knob until the display reads 25 cm H₂O. The RT-200, OR EQUIVALENT TEST EQUIPMENT must display a pressure of 25 cm H₂O $\pm$ 0.7cm H₂O.

Set the CPAP pressure to 10 cm H₂O. Verify a pressure of 10 cm H₂O $\pm$ 0.7 cm H₂O.

Set the CPAP pressure to 2 cm H₂O. Verify a pressure of 2 cm H₂O $\pm$ 0.7 H₂O.

IPAP Pressure Check

▼ Connect the flow restrictor to the end of the Quantum's outlet. Connect the 1/8" tubing on the flow restrictor to a pressure measuring device.

Select the Spontaneous/Timed mode on the Quantum. Set the Quantum parameters to the following:

CPAP/EPAP	2cm H ₂ O
IPAP	
Domestic Units	30cm H ₂ O
International Units	37cm H ₂ O
35cm H ₂ O Units	35cm H ₂ O
Risetime	0.1 seconds
Rate	10 BPM
%I Time	50

SECTION 10.0

Calibration and Testing

Verify that the following pressures are obtained:

Domestic Units	Low Pressure: 2cm H ₂ O ± 0.7cm H ₂ O High Pressure: 30cm H ₂ O ± 0.7cm H ₂ O
International Units	Low Pressure: 2cm H ₂ O ± 0.7cm H ₂ O High Pressure: 37cm H ₂ O ± 0.7cm H ₂ O
35cm H ₂ O Units	Low Pressure: 2cm H ₂ O ± 0.7cm H ₂ O High Pressure: 35cm H ₂ O ± 0.7cm H ₂ O

IPAP Pressure Check

(Continued)

Set the IPAP pressure to 5 cm H₂O, verify the high pressure is 5 cm H₂O ± 0.7 cm H₂O on all units.

▼ Connect an unrestricted adapter (TS-7700-032) to the Quantum patient outlet. Connect the 1/8" ID tubing to the tee on the adapter. Connect a short piece of 22mm OD tubing to the adapter, and the other end to a gate valve (90902). Using another short piece of 22mm OD hose, connect the other end of the gate valve to a flow meter, (see figure 3).

Turn on the Quantum and set the mode to CPAP. Set the CPAP pressure delivery to 5 cm H₂O.

Completely close the gate valve in the circuit and verify that the flow reading is 0.00 LPM on the flow meter. With the gate valve close, verify that the CPAP pressure is 5.00 ± 0.7 cm H₂O.

Open the gate valve until the flow reaches 150 LPM, or the gate valve is completely open, as indicated by the flow meter. Verify that the pressure is 5.00 ± 0.7 cm H₂O.

Low Pressure CPAP Performance Check

▼ Connect an adapter (TS-7700-032) to the Quantum patient outlet. Connect the 1/8" ID tubing to the tee on the adapter. Connect a short piece of 22mm OD tubing to the adapter, and the other end to a gate valve (90902). Using another short piece of 22mm OD hose, connect the other end of the gate valve to a flow meter, (see figure 3).

Turn on the Quantum and set the mode to CPAP. Set the CPAP pressure delivery to 25 cm H₂O.

Completely close the gate valve in the circuit and verify that the flow reading is 0.00 LPM on the flow meter. With the gate valve close, verify that the CPAP pressure is 25.00 ± 0.7 cm H₂O.

Open the gate valve until the flow reaches 150 LPM, or the gate valve is completely open, as indicated by the flow meter. Verify that the pressure is equivalent to the previously measured pressure ± 0.7 cm H₂O.

High Pressure CPAP Performance Check

Calibration and Testing

**Spontaneous Mode
Performance Test**

▼ Connect the portable inspiration simulator (7700-18 Test Kit) to the unit with a 22mm hose. Check that the bias hole is not blocked on the portable inspiration simulator. Cover both the 0.35 lps and the 0.075 lps holes with your fingers. After 10 seconds, uncover the 0.075 lps hole. The unit must not detect an inspiration.

Wait another 10 seconds and uncover the 0.35 lps hole. The unit must detect an inspiration.

**Spontaneous/Timed
Mode Performance
Check**

▼ Set the unit mode to Spontaneous/Timed. Connect the Quantum to the Michigan Lung using a 22mm hose. Set the Michigan Lung to the following settings:

Proximal Resistance	Rp20
Lung Resistance	Rp50
Lung Compliance	0.03

Set the system settings to the following:

CPAP/EPAP	10 cm H ₂ O
IPAP	25 cm H ₂ O
Risetime	0.3 seconds
Rate	10 BPM
%I Time	25

Using a stopwatch, time five breathing cycles.

Note: This is accomplished by establishing the point when the forced breath LED illuminates.

Verify that the five breathing cycles take 30 seconds $\pm$ 1 second to complete. Verify that the forced breath LED, located to the left of the Rate display, illuminates during each breath.

Reset the Michigan Lung to the following parameters:

Proximal Resistance	Rp5
Lung Resistance	Rp20
Lung Compliance	0.05

Verify that the five breathing cycles take 30 seconds $\pm$ 1 second to complete. Verify that the forced breath LED, located to the left of the Rate display, illuminates during each breath.

SECTION 10.0

Calibration and Testing

▼ Connect a flow restrictor to the Quantum's patient outlet. Set the unit to the following parameters:

CPAP/EPAP	5 cm H ₂ O
IPAP	15 cm H ₂ O
Risetime	0.1 seconds
Rate	10 BPM
%I Time	50

The unit defaults to the EPAP pressure, and the barograph displays 5 cm H₂O. After 3 seconds $\pm$ 0.5 seconds, the barograph increases to 15 cm H₂O for 3 seconds $\pm$ 0.5 seconds.

Set the Quantum to the following parameters:

CPAP/EPAP	5 cm H ₂ O
IPAP	15 cm H ₂ O
Risetime	0.1 seconds
Rate	5 BPM
%I Time	25

The unit defaults to the EPAP pressure, and the barograph displays 5 cm H₂O. After 9 seconds $\pm$ 0.5 seconds, the barograph increases to 15 cm H₂O for 3 seconds $\pm$ 0.5 seconds.

Set the Quantum to the following parameters:

CPAP/EPAP	5 cm H ₂ O
IPAP	15 cm H ₂ O
Risetime	0.1 seconds
Rate	20 BPM
%I Time	66

The unit defaults to the EPAP pressure, and the barograph displays 5 cm H₂O. After 1 second $\pm$ 0.5 seconds, the barograph increases to 15 cm H₂O for 2 seconds $\pm$ 0.5 seconds.

▼ With the unit running, unplug the AC power cord from its supply. The alarm must sound for at least five seconds, and the red Power LED must illuminate immediately. Plug the AC power cord back into its supply. The alarm must cease.

Approximate Timing Verification

Power Alert Check

Calibration and Testing
Patient Alert Check

▼ Connect a flow restrictor (TS-7700-031) to the outlet port. Set the parameters to the following:

CPAP/EPAP	5 cm H ₂ O
IPAP	30 cm H ₂ O
Risetime	0.3 seconds
Rate	4 BPM
%I Time	50

Remove the flow restrictor (TS-7700-031) from the outlet port. The alert sounds within 30 seconds of removing the flow restrictor. The alert is silenced by replacing the flow restrictor on the outlet port.

System Alert Check

▼ Set the Quantum to CPAP mode. Set the CPAP pressure to 10 cm H₂O. Connect a 20 cm H₂O positive pressure source (7300 or equivalent) to the outlet port of the unit. Block the exhalation port on the rear panel of the unit. The alert sounds, when the pressure exerted exceeds 5 cm H₂O for 0.5 seconds. To reset the alert, turn off the unit.

Estimated Parameters Check

▼ Set the unit mode to Spontaneous/Timed mode. Connect the Quantum to the Michigan Lung using a 22mm hose. Set the Michigan Lung to the following settings:

Proximal Resistance	Rp5
Lung Resistance	Rp20
Lung Compliance	0.05

Set the system settings to the following:

CPAP/EPAP	2 cm H ₂ O
IPAP	25 cm H ₂ O
Risetime	0.1 seconds
Rate	10 BPM
%I Time	25

Let the unit stabilize for one minute before reading displays. Verify that the unit displays the following estimated parameters:

Minute Vol	17.80 ± 5.34
Tidal Vol	1.780 ± 0.534
Rate	10

SECTION 10.0



Calibration and Testing

▼ Connect a 7703 Remote Unit to the rear panel of the Quantum Main Unit. Verify that adjusting the controls on the Remote Unit changes the displays on the Main Unit. Verify that the readings on the Main Unit match those displayed on the Remote Unit. Perform the Alert checks to verify that the Main Unit transmit alert signals to the Remote Unit.

Communication Port Check

▼ Using a mini-phono plug, connect the positive lead of a volt-meter to the tip of the phono plug, and the negative lead to the sleeve of the phono plug. Select the CPAP mode on the unit. Set the CPAP pressure to 15 cm H₂O.

Analog Pressure Output Check

Connect the unit to a pressure measuring device using a flow restrictor and 3/16" tubing, (see figure 2). Verify that the unit pressure is 15.0 ± 0.7 cm H₂O on the pressure gauge.

Refer to the following formula to determine the voltage measure range measured at the above pressure:

$$\frac{\text{Pressure Measured (cm H}_2\text{O)}}{10} = \text{voltage} \pm 0.05 \text{ volts}$$

Calibration and Testing
System Final Test

Serial No.: _____

Notification No.: _____

CPAP Pressure Check:

	25 cm H ₂ O	10 cm H ₂ O	2 cm H ₂ O
Pressure			
Specs	± 0.70	± 0.70	± 0.70

IPAP Pressure Check:

	Domestic 30 cm H ₂ O	International 37 cm H ₂ O	35 cm H ₂ O 35 cm H ₂ O
IPAP Specs	± 0.70	± 0.70	± 0.70
	2 cm H ₂ O	2 cm H ₂ O	2 cm H ₂ O
EPAP Specs	± 0.70	± 0.70	± 0.70

Pre Run-In Hours	Post Run-In Hours

 Low Pressure CPAP
Performance Check:

LPM	0 LPM	150 LPM	Difference
5 cm H ₂ O			± 0.70

 Power Alert: Pass ☐ Fail ☐

 Patient Alert: Pass ☐ Fail ☐

 System Alert: Pass ☐ Fail ☐

 High Pressure CPAP
Performance Check:

LPM	0 LPM	150 LPM	Difference
25 cm H ₂ O			± 0.70

 Approximate Timing
Verification: Time

 Spontaneous Mode Performance Check: Pass ☐ Fail ☐

 Spontaneous/Timed Mode
Performance Check:

	Rp20 (Proximal Resistance)	Rp5
30 sec.	30 sec.	
± 1 sec.	± 1 sec.	

5 Breaths

10 BPM/50 %I

5 BPM/25 %I

20 BPM/66 %I

Specs

	IPAP	EPAP
	3 sec.	3 sec.
	3 sec.	9 sec.
	2 sec.	1 sec.
	± 0.5 sec.	± 0.5 sec.

 Estimated Parameters
Check:

Minute Vol	17.80 ± 5.34	
Tidal Vol	1.780 ± 0.534	
Rate	10	

 Safety Test: Pass ☐ Fail ☐

 Comments:

PASS

Tested By: _____

FINAL
FAIL

Date Tested: _____

Parts List

Parts List

Section 11.0

Service Kits
Parts List

Service Kits

▼ The following lists the service kits that contain replacement parts that are used throughout this manual.

H7700-18 Test Kit

Includes:

Y-Tube Simulator
Restricted, Connector, Aprt 22 mm (Test Kit)
Unrestricted, Coupler, 22 mm I.D. (Test Kit)

H7719 Filter Air Intake Screen

Includes:

Filter Air Intake Screen

H7780 Dual Impeller (New Style) Blower Kit

Includes:

Motor/Blower Assembly
Screws
Flat Washers
Blue Isolators
Foam
Box

H7781 Single Impeller (Old Style) Blower Assembly Kit

Includes:

Single Impeller (Old Style) Blower Assembly
Motor
Impeller
Balancing Disk
Lower Housing
Motor Cover
Brass Fitting for Motor Cover
Screws (4)
Washers (4)
Frame With /Integral Filter Screen
Tubing 1/16" X 1/8" Clear
Tubing 1/8" X 1/4" Black
Tubing 1/8" X 1/4" Green
Fitting 10-32 X 1/8" Single Female
Fitting 1/8" IDX #10-32 Adjustable
Fitting 1/16" Barb x #10-32 THD Brass
Foam, Upper Blower
Foam, Lower Blower
Foam, Flowmeter Insulation
Hose, Patient Air
Valve Hose
Hose Overboard Dump

Parts List

H7782 Valve Assembly -06 Kit

Includes:

- Valve Assembly
- Tie Wraps (2)
- Screws
- Tie Mounts

Service Kits
(Continued)

H7783 Valve Assembly -07 Kit

Includes:

- Valve Assembly
- Tie Wraps (2)
- Screws
- Tie Mounts

H7792 Pressure Switch Bracket Assembly Kit

Includes:

- Bracket
- Pressure Switch
- Screws

**H7784 Basic Service Single Impeller (old style) Blower Kit
(Kit can service 6 Units)**

Includes six each:

- Filters
- Hoses (-01)
- Hoses (-02)
- Expandaflex Hose
- Screws with integral washers
- Spill Curtain
- Foam Circle around spill curtain

**H7785 Basic Service Dual Impeller (New Style) Blower Kit
(Kit can service 6 Units)**

Includes six each:

- Filters
- Hoses (-03)
- Hoses (-04)
- Expandaflex Hose
- Screws with integral washers
- Spill Curtain
- Foam Circle around spill curtain

H7786 Air Intake Assembly Kit

Includes:

- Air intake
- Screws

H7787 Front Bezel Kit, English

Includes:

- Front/Bezel
- Screws

Service Kits

(Continued)

H7787-00 Front Bezel Kit, English, French, German, Italian, Spanish

Includes:

Front/Bezel
Screws

H7787-10 Front Bezel Kit, Swedish, Dutch, Danish, Greek, Finnish

Includes :

Front/Bezel
Screws

H7788 Front Panel Assembly

Includes:

Front Panel
Overlay
Screws

H7788-xx Front Panel Assembly, Language Specific (xx ending same as finish goods ending)

Includes:

Front Panel
Language Specific Overlay
Screws

H7789 Valve Clean Up Kit

Includes for six valves:

#10-32 X 1/8 Brass Fitting
#10-32 Adjustable Fitting 1/8 IDX
1/8 X 1/4 Vinyl Red Tubing
1/8 X 1/4 Vinyl Blue Tubing
3/8" Diameter Heat Shrink Tubing
Foam, Inlet Gasket
Foam, Outlet Valve
Tie Mount

H7790 Enclosure Assembly Kit (foam for both old and new version)

Includes:

Enclosure
Foam (Old Revision)
Foam (New Revision)

H7791 Fuse Kit

Includes:

Fuse Drawer
Fuses (2)

Theory of Operation

Theory of Operation

Section 12.0

System Components
Main Unit Internal Components
Remote Unit Internal Components
Physical Board Arrangement
Power Distribution
Power On/Off Control Subsystem
Alarm Circuit Subsystem
Encoder Board
Display Board
CPU Board
Control Board

System Components

▼ The Model 7700 Pressure Support Ventilator (PSV) system consists of a Main Unit and a Remote Unit, (see figure 21). The Main Unit is the pressure source and primary control center for the system. It is most often used as a stand-alone device, but can be controlled up to 100 feet away with an optional Remote Unit. When it is installed, either the Main or Remote front panel can control the Main Unit pressure delivery settings. A single cable connects the Main to the Remote, handling bi-directional serial communications and delivering power to the Remote. Both Main and Remote Units feature chart recorder outputs, providing both Output Pressure and Flow signals. Additionally, the Main Unit has a modem connection port. When connected, remote control of the PSV system is possible via telephone lines. When the modem is connected, control from the Remote Unit is automatically disabled.

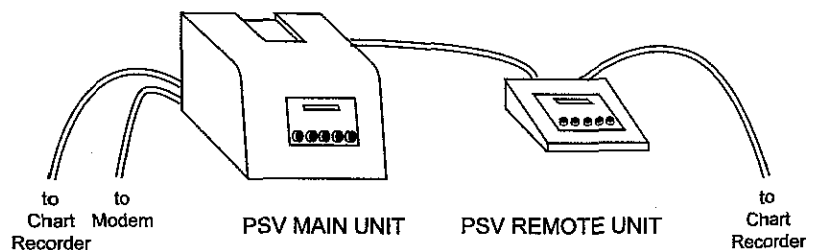


Figure 21: *System Components*

Main Unit Internal Components

▼ The Main Unit's primary electrical components consist of five circuit boards and various off-the-shelf devices. Refer to the Main Unit Internal Components diagram below. External AC power enters through a rear-panel appliance block, which contains the main fuse. The appliance block sources power to the main power supply. The supply generates +24V as the main DC rail of the device. It sends +24V to the Control Board, which serves as the DC power distribution point for the internal components.

The five circuit boards in the device include the Encoder, Display, CPU, Control, and Sensor boards. The Encoder Board receives the front panel knob settings. It sends these to the Display Board, which contains the remaining front panel displays and switches, and associated drive/interface circuitry. Together, the Encoder and Display Boards make up the electrical front panel operator interface.

The CPU Board's primary role is as a waveform generator that creates the device output pressure profile. It uses the operator input information from the Display and Encoder Boards to create the profile. It then sends this to the Control Board, which drives the electromechanical devices that actually delivers the pressure.

These device include a Valve Actuator and Motor. The motor turns a centrifugal blower that develops the pressure source. The Valve Actuator is part of a valve assembly that operates as a variable restrictor to regulate the pressure delivered from the blower. Additional devices that interface to the Control Board include the Fan for power supply cooling, and the Sonalert (audible alarm) for user alert conditions.

Theory of Operation

The Sensor Board receives the pneumatic connections to detect required pressure and flow data. It contains transducers that convert air pressure and flows into electrical signals, and sends these to the Control Board. Using this information, the Control Board compares the desired pressure from the CPU Board to the actual pressure from the Sensor Board and uses closed loop control to command the Valve Actuator and Motor. In this way the actual pressure delivered follows the desired pressure settings on the operator interface. The Control Board also includes some flow signal processing. In certain operation modes, it coordinates its pressure fluctuations with the patients own respiration demands to provide respiratory support just when it is needed.

Main Unit Internal Components (Continued)

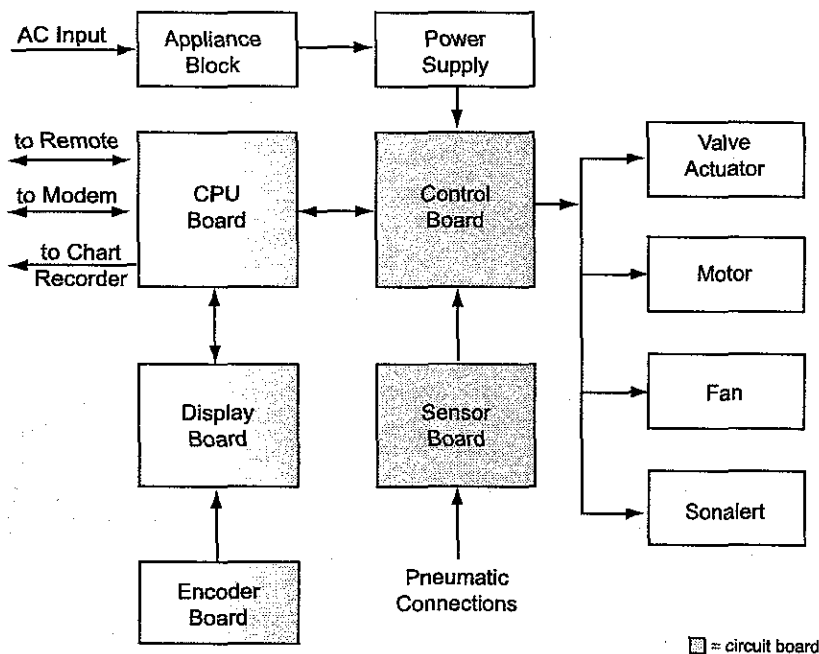


Figure 22: Main Unit Electrical Components

▼ The Remote Unit is an optional system component. It is used most often in sleep clinics where a therapist in a centralized control room supervises the therapy or the diagnostic procedures for nearby patients in sleeping rooms. Except for the On/Off function, the Remote makes use of all of the PSV's front panel controls, accessible up to 100 feet away from the Main Unit.

An 8-conductor (plus shield) cable connects the Main and Remote units, providing two-way serial communications and power to the Remote. Inside are duplicates of three of the Main Unit's circuitry boards. The Encoder board is identical, but the Display and CPU Boards are populated slightly differently.

The serial communications along with +24V power arrives via the cable to CPU Board. An on-board DC-to-DC converter develops the logic and analog level voltages. A jumper on the CPU Board indicates its Remote Unit context. The firmware, which is identical to the Main Unit version, detects the jumper and

Remote Unit Internal Components

Remote Unit Internal Components

(Continued)

enters the remote mode of operation. In simple terms, it disables the pressure waveform generator task, and configures the communications protocol for the remote function.

The Remote Unit's chart recorder jacks output the same pressure and flow information as the chart recorder output jacks on the Main Unit. Real-time pressure and flow data are contained in the communications protocol between the two devices.

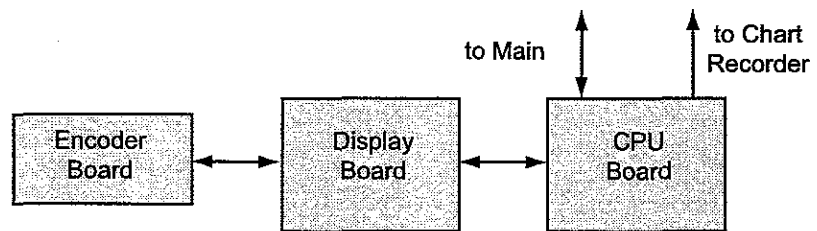


Figure 23: *Remote Internal Electrical Components*

The Remote may be plugged into the Main Unit or unplugged during normal operation without adverse effects. Both the units require the user to set them to "control" mode before the user may change the control settings. Both sets of control settings may be enabled simultaneously. Software in the Main PSV simply does a logical OR on the settings. The last device to direct a parameter change determines the current setting.

Physical Board Arrangement

▼ The Display Board forms the main part of the operator interface. As such, it is parallel to the plane of the front panel, and fastens to it. The encoder fastens to the rear of the Display Board, which features through-holes for the encoder shafts.

A dual row header connector on the Encoder Board connects through the rear of the Display Board into a bottom-entry connector. The CPU Board interfaces to the Display Board through a short 50-pin ribbon cable (a longer cable version connects them in the Remote Unit).

The Control Board has a 50-pin dual row header that plugs into a rear-entry connector on the CPU Board. These pins may be extended in length to accept a test connector. The Control Board and Sensor Board connect via a small ribbon cable. The Control Board connects to other electromechanical devices in the system through specialized cable harnesses that have individual signal wires.

Theory of Operation

▼ The PSV 24 VDC power distribution network stretches across all the circuit boards in the system, (see figure 24).

Power Distribution

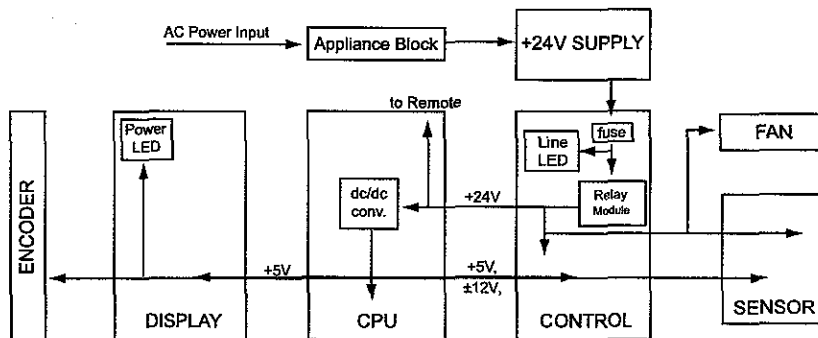


Figure 24: Power Distribution System

External AC power enters the PSV's main power supply. It converts 110 or 220V to 24VDC. Whenever the PSV is plugged into a live wall outlet, the internal 24V supply is on. From there the 24V supply output enters the Control Board. A fast-blow 5A fuse soldered on the board protects the +24V supply from load fault conditions. Industry regulations require a visible indicator that monitors the status of AC input power. The "Line LED" on the Control Board serves that purpose. The board extends to the rear of the unit chassis. The LED is located along the rear edge of the board, and is visible through a hole drilled in the rear chassis panel.

The Control Board also happens to be the main consumer of power in the system, because of the blower motor controller and valve actuator amplifier. Therefore, the master power relay module is located on this board. The relay module is energized by the Power On/Off Control Subsystem. When the relay module is energized, the unit is "On". When the user turns on the unit, the relay module turns on and the Control Board sends +24V power to a few devices that use +24V directly. Additionally, the 24V power goes to the CPU Board, where a DC-to-DC converter generates +5V for logic power and $\pm 12V$ for analog and serial communication power.

The CPU board sends the +24V on to a Remote Unit, if connected. Then also sends +5V only to the Display Board, which in turn sends that on to the Encoder Board. The Display Board is the main consumer of +5V. The CPU Board also sends +5V and $\pm 12V$ to the Control Board, which sends these voltages including +24V on the Sensor Board. The Sensor Board and/or Control Boards may post regulate $\pm 12V$ to $\pm 8V$ for noise decoupling, etc..

Power Distribution (Continued)

The Remote Unit receives +24V via the remote cable. It enters the CPU Board of the Remote, and powers the on-board DC-to-DC converter directly. The Remote Unit is powered whenever the Main Unit is powered.

Power On/Off Control Subsystem

▼ The power On/Off Control Subsystem accepts the user's front panel power switch input and alternately energizes or de-energizes the master power relay module (see figure 25).

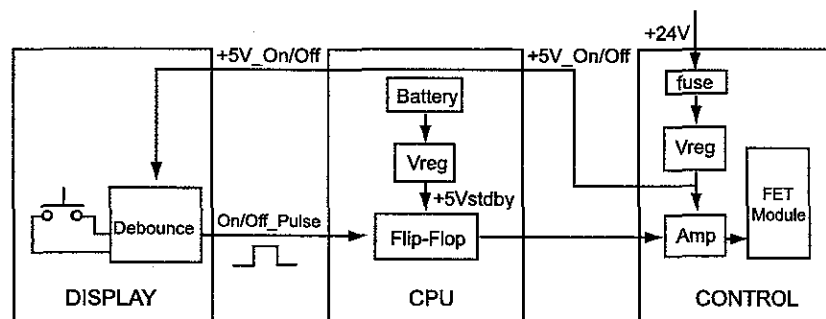


Figure 25: Power On/Off Control System

The Control Board receives +24V whenever the PSV receives external power. After the fuse, there is a low power regulator circuit that generates +5V_On/Off. This is a power rail specifically for running the front panel on/off function. The Control Board passes that voltage through the CPU Board to the Display Board. Even when the unit is technically "off", the Display Board's front panel switch is powered to turn the remainder of the unit on.

The front panel Power Switch is a spring loaded, momentary, normally open switch. The debounce circuit which is powered by +5V_On/Off responds to a switch close-open cycle and generates a pulse. A flip-flop circuit on the CPU Board toggles alternately high and low with each successive pulse received. It is important to note that this flip flop is powered from the CPU's on-board battery, through a regulator. When a power failure occurs, the state of the flip-flop is preserved. If external power returns, the unit automatically turns on again. The flip-flop output goes to a transistor-switch amplifier on the Control Board. This energizes the relay module, which then closes the relay contacts and delivers +24V to the whole system.

Theory of Operation

The physical locations of these circuit functional blocks are the result of the following considerations. The power switch and debounce circuit are located on the Display Board in order to be physically near the switch, and to off-load circuitry from other boards in the system. the flip-flop resides on the CPU Board along with the battery. This establishes a connection from the battery to the flip-flop power input pin that has no connector to make/break, besides the battery holder itself. This feature provides for a more reliable system, that only turns on or off when it is supposed to.

Power On/Off Control Subsystem (Continued)

▼ The Alarm Circuit encompasses components on several circuit boards. However, the core logic section is on the Control Board, (see figure 26).

Alarm Circuit Subsystem

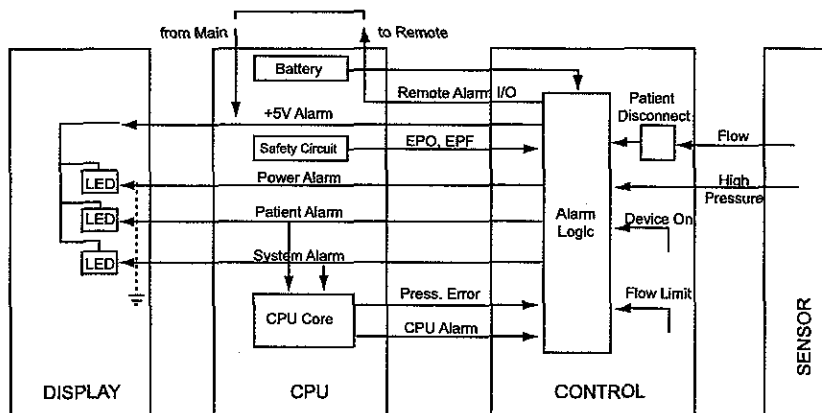


Figure 26: Alarm Subsystem

The PSV Main Unit features both audible and visible alarms for the three conditions: Power Fail Alarm, Patient (disconnect) Alarm, and System Alarm. A Power Fail Alarm occurs after a loss of external power while the device is on. A Patient Alarm may occur during normal operation if high flows persist, indicating the patient's mask is off. A System Alarm may occur during normal operation at the onset of a pressure error or other error condition detected by the CPU. The Display Board features an LED for each alarm. An internal audible alarm coincides with either of the three alarms.

The Remote Unit's front has three alarm LEDs also, but they illuminate in unison to indicate a general alarm condition. Since the Remote Unit has no audible alarm, its three LEDs flash on and off during an alarm condition to attract attention. To learn which of the three alarm condition(s) exist, the user must go to the Main Unit and observe its front panel.

The Alarm Logic block accepts inputs to generate the three different alarms. The Sensor Board outputs a Total Flow signal, which is processed on the Control Board. Part of that processing includes the detection of a patient disconnect, generally related to high flows for more than 20 seconds. The Sensor Board also provides a high pressure signal, generated from an over-pressure switch monitoring blower pressure.

Theory of Operation

**Alarm Circuit
Subsystem**
(Continued)

The Alarm Logic block detects an unintended (by the user) loss of power, and generates a Power Fail alarm. The CPU Board's CPU core microcontroller compares the desired pressure to the actual pressure and generates the signal Press Error when a discrepancy occurs. This error may be disqualified by a Flow Limit condition on the Control Board, however. The microcontroller may also generate a CPU alarm in the case of a diagnostic failure or other internal error. Either of the three signals Press Error, CPU Alarm, and High Pressure causes the Alarm Logic block to output a System Alarm. The CPU Core monitors the Patient Alarm and System Alarm lines, which may be asserted from conditions not otherwise visible to the CPU. In this way the CPU may report via a modem device any existing errors.

During normal PSV operation the +12V rail powers the Alarm Logic section. Simultaneously, the CPU Board's charging circuit maintains a trickle charge to the on-board battery. When an external power failure occurs, the alarm circuit issues a Power Fail Alarm for up to 10 minutes. During this time, the CPU Board's battery powers the alarm circuit.

The Alarm Subsystem diagram, (figure 26), serves to illustrate both Main and Remote Unit implementation of the circuit boards shown. In the Remote, only the left two boards in the diagram apply. In the Main version, note the three alarm lines originating on the Control Board, passing through the CPU Board, and going on to the Display Board. There they illuminate the three corresponding LEDs on the front panel. These three alarm lines drive individual "low sides" of the LEDs. The LEDs have a common "high side". However, this common power rail has two possible origins, depending on whether the situation is Main or Remote.

In the Main case, the Alarm Logic block on the Control Board provides the +5V_Alarm rail as a steady voltage, while sending out a pulsing, active high rail called "Remote Alarm I/O" to the Remote Unit in order to flash its LEDs.

Now, view the Alarm Subsystem diagram with respect to the Remote Unit case. The Control and Sensor boards are not present. the +5V_Alarm line is now not driven by a Control Board, but is driven instead by the pulsing Remote Alarm I/O signal arriving from the Main Unit. On the Display Board, the three individual low side LED lines are all tied to ground, so that any common high side pulse flashes all three LEDs together. The detailed schematic description is located in the Control Board section of the Theory of Operation.

Encoder Board

▼ The user interface on the front panel of the PSV features five control knobs. By turning these a user may adjust desired pressure waveform settings. The goal is to have analog-like controls which are intuitive to use, but with digital readouts that allow precise settings that do not drift over time. In a hospital environment it is desirable to have parallel access to any of the main controls (without having to scroll through menus, etc.). Moreover, the Remote Unit must be able to control the PSV while the PSV's controls are still enabled, without conflict. In order to meet these requirements, we use low-cost rotary resistive digital encoders, made by Bourns.

Theory of Operation

Each encoder turns infinitely in either clockwise or counterclockwise direction. The version with 12 mechanical detents per revolution is used. There are three electrical connections per encoder: Channel A, Channel B, and Common. Inside the encoder is a resistive disk that alternately connects/disconnects Channel A and Channel B with the Common pin. When the encoder disk rotates, the signals on Channel A and B generate an industry-standard sequence. From it, decoding circuitry tells the direction of rotation and count each increment (or phase) of rotation, (see figure 27).

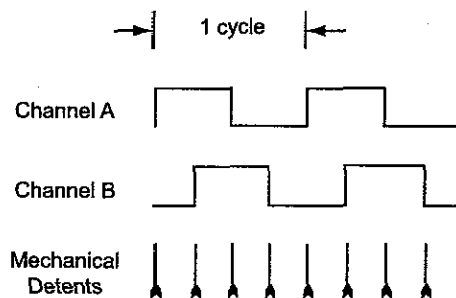


Figure 27: *Phase of Rotation*

In the PSV, the microcontroller on the CPU Board reads the encoder signals on an interrupt scan basis. The relationship between encoder position and its associated control parameter is completely S/W determined. At the end of each parameter range, a S/W limit takes effect. Further encoder turns toward out-of-range are ignored. Turns back toward the operational range take effect immediately. In some PSV modes, a particular control parameter may not be applicable. In those modes, S/W simply ignores those encoders.

Refer to the Encoder PCB schematic. Each encoder has a common pin and two channel pins. The common pin (pin 2) ties to digital ground. Each channel pin (pins 1 and 3) require a pullup resistor, 4.75k to +5V. The internal encoder contacts have a contact bounce time of less than 5 mS. After the pullup resistor, each channel has an RC network. Its design filters out contact bounce transients faster than 5 mS.

Note that the maximum detent rate (mechanical speed) at which the encoder may rotate and be detected is twice the RC filter limit, because the two channels have alternating transitions. The filtered channel signals go to a header connector that plugs in through the back of the Display Board.

▼ The Display Board contains all of the front panel numeric displays and other visible indicators required as part of the operator interface. The same PCB is used in the Main and Remote versions, but populated slightly different. The chief difference is that the main version has a power on/off switch while the remote version does not.

The Display Board and its components are the most physically constrained of any in the system. Most of its components must align precisely with window cut-outs in the front panel. Component height is also critical. Included with its display devices are four push-button switches (momentary type), for the mode

Encoder Board (Continued)

Display Board

Display Board

(Continued)

up/down and patient data up/down features. The Encoder Board's encoder channel signals enter the Display Board through a connector. The Display Board adds Schmitt trigger inverters on each of the lines, and passes the outputs on to the CPU Board as data inputs.

All of the display devices are LEDs, in various packages. The display is multiplexed. The microcontroller on the CPU Board drives the multiplexing, performing regular display updates on an interrupt basis. The interface is mostly parallel, so the CPU spends little time on each display update in writing the data to the Display Board.

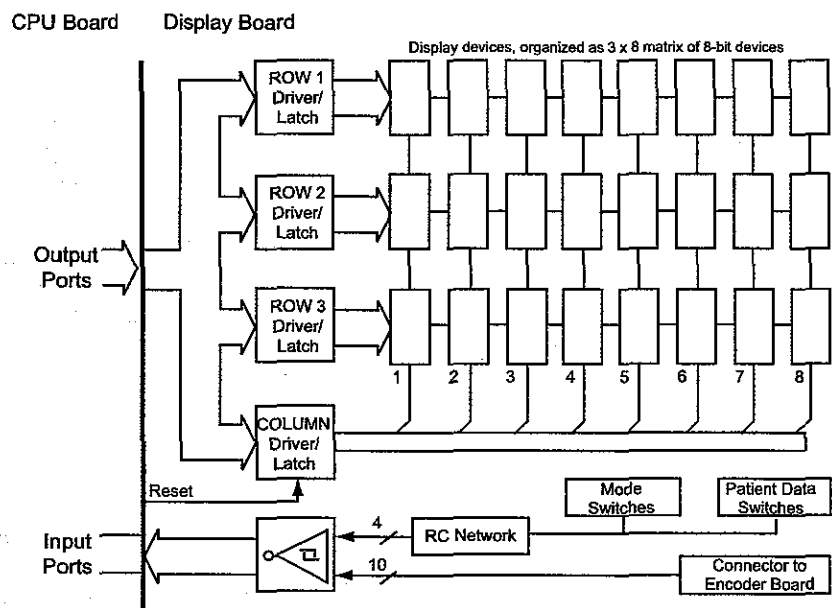


Figure 28: Display Board Block Diagram

The CPU Board interface to the Display Board uses almost four full 8-bit I/O ports. The WSI PSD401-A1 "programmable system device" chip helps out the microcontroller by adding 5 eight-bit ports, providing most of the interfaces. The display devices include 7-segment (plus decimal point) displays, barographs, and discrete LED lamps. All are organized as eight bit entities. These entities are then organized into three rows by eight columns. The CPU's multiplexing scheme turns on only one column at a time. When logically on, each LED is actually on only $\frac{1}{8}$ of the time. However, the current is elevated so they operate at a more efficient current/intensity point. They shine briefly, but brightly. The eye of the viewer averages the intensity so the LEDs appear on all the time.

The update rate for the entire display is approximately 92 Hz, corresponding to a period of 10.9 mS. The CPU writes the "segment" data (8 bits) to each of the row latches. Then it turns on column 1. Because there are eight columns, each column is on for $\frac{1}{8}$ of a scan, or 1.35 mS. Next the CPU turns off column

Theory of Operation

1, writes new data to the row latches, and turns on column 2. This procedure continues until all eight columns have been illuminated. Then, the process starts over with column 1.

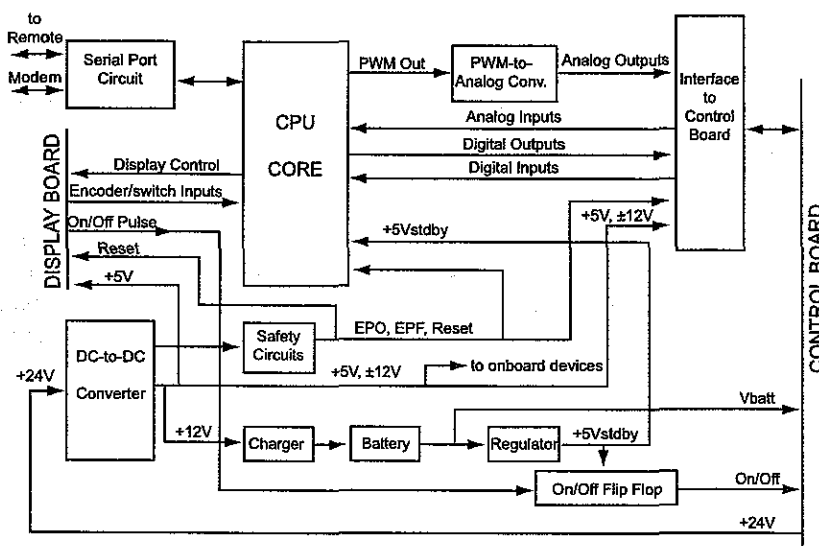
At power-up, Reset* is asserted. The Display Board utilizes this signal to blank the displays. The data latches do not have "clear" control pins, and may contain "1" bits that can turn on random LEDs during the reset period. During power-up diagnostics, the CPU turns on all LEDs as a lamp test. During this time the Display Board consumes nearly twice the +5V power of normal operation. The power supply design takes this into account. The Remote Unit power up behavior is the same as the Main Unit.

Display Board (Continued)

▼ The primary role of the CPU function in the PSV design is to generate the desired pressure waveform or profile. As a waveform generator, the CPU Board also serves as an integral part of the operator interface. Through the interface provided, the user can tailor the pressure waveform in terms of levels, duty cycles, timing, and so on. The Control Board is central to the role of ensuring the actual PSV output pressure matches the CPU Board's pressure command (desired pressure). In the Remote version of the board, the interface to the Control Board is not populated. It therefore serves as an operator interface, and communicates to the Main unit via a serial interface. There are several functional blocks in the CPU Board, (see figure 29)

CPU Board

We first describe the block diagram in general terms, and thereafter go into the schematic in more detail. The CPU core contains a microcontroller and its peripheral devices. The CPU has a parallel interface to the front panel. Using a periodic scan, it reads the encoders and updates the displays. The display is a multiplexed arrangement that requires constant refresh writes from the CPU. The serial port circuit consists of a differential transceiver RS422 interface for Main-to-Remote Unit communications, and transceivers for RS232 communications to a modem device. There is only one serial port in the CPU core, so the two receive lines switch between the Remote or modem devices.

CPU Board
 (Continued)

Figure 29: CPU Board Block Diagram

The DC-to-DC converter accepts +24V from the Control Board and generates logic and analog rails (+5V, $\pm 12V$). A safety circuit monitors the power supply and generates power-up Reset, Early Power fail (EPF, and Early Power On (EPO)). EPF warns the CPU that a power failure is eminent, so it may have an orderly shutdown. EPO announces a power-up, so that a power fail alarm in the alarm circuit may be reset. The CPU Board contains a rechargeable 9V NiCad battery. When on, the unit constantly trickle charges the battery. A special low-standby current regulator connected to the battery generates +5V standby, for the purpose of memory retention of RAM contents. It also powers a flip-flop which stores the on-off state of the unit. The CPU core uses pulse-width-modulation outputs for scalar outputs. On-board circuitry converts the pulse width into analog voltages. A generic CPU Core-to-Control board interface includes five each analog inputs and outputs, and four each digital inputs and outputs.

CPU Core

The microcontroller (U1) is an Intel 80C196 running at 12 MHz. A Programmable System Device (PSD) made by wafer Scale Integration (U2) contains virtually all digital peripherals to complete the BPU core. Inside it are the CPROM, RAM, address decode PAL, a PLD area, and five 8-bit ports. A binary counter IC (U3) serves as a clock divider and generates a serial port baud rate reference, fed back to the processor's serial port circuit.

The PSD401-A1 programmable system device is specially configured with firmware to the required bus decode logic for the Intel 8096 family microcontroller. It requires a clock (5MHz) to synchronize with the processor. It receives the bus control signals from the 80C196 and decodes address and data information. The PSD401-A1 also contains an address decode map that generates internal "chip selects" for various peripherals, such as operating

Theory of Operation

system EPROM, RAM and I/O ports. Its RAM is battery backed via pin 28, "Vstdbv". On the remote version this just ties to +5V. Nearly all of the PSD401-A1's port pins are programmable as inputs or outputs. Most of the port pins interface to the Display Board. The remaining port handles the serial port control lines.

The generic interface strategy to the Control Board is shown in the figure 30. This is to aid in board-level testing, and to provide for future expansion needs. Inverters on the digital lines serve for protection and to achieve active low operation for better noise margins. DOUT0-3 outputs of U2 are inputs by default at power-up, so they require pull-down resistors to avoid floating at powerup.

Jumper block J1 may contain up to five configuration jumpers. Currently only the first jumper is used. If populated, the processor knows the board is a Remote Unit. Otherwise, it is a Main Unit.

Resistor network R97 is populated on Remote versions to avoid floating inputs to the processor when the Control Board interface is depopulated. The processor contains eight analog inputs, of which five are used. They resolve 10 bit values over an input range of 0V to 5.11V. The Vref input voltage powers the analog portion of U1 and also determines the full scale analog input value that may be converted. Diodes on this line keep it within close range to U1's Vcc input, as it requires. Each analog input line has a simple RC filter to improve noise and ESD immunity. The digital inputs also have RC networks for the same reasons. The +5Vstdbv input on U2 carries the voltage from the battery circuit that keeps the static RAM contents intact during power outages. In the remote version, this line is jumpered to +5V because the battery is not populated.

CPU Board

(Continued)

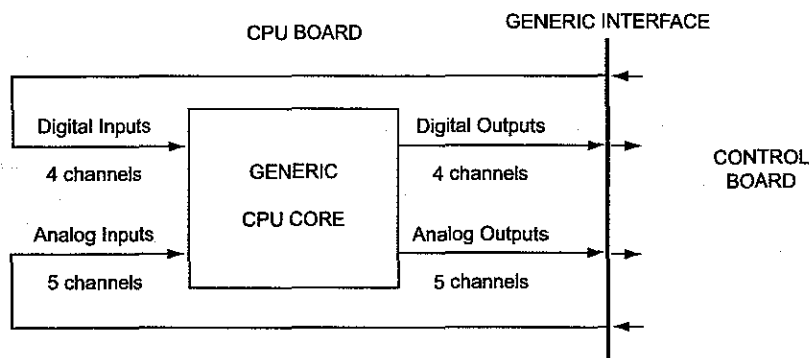


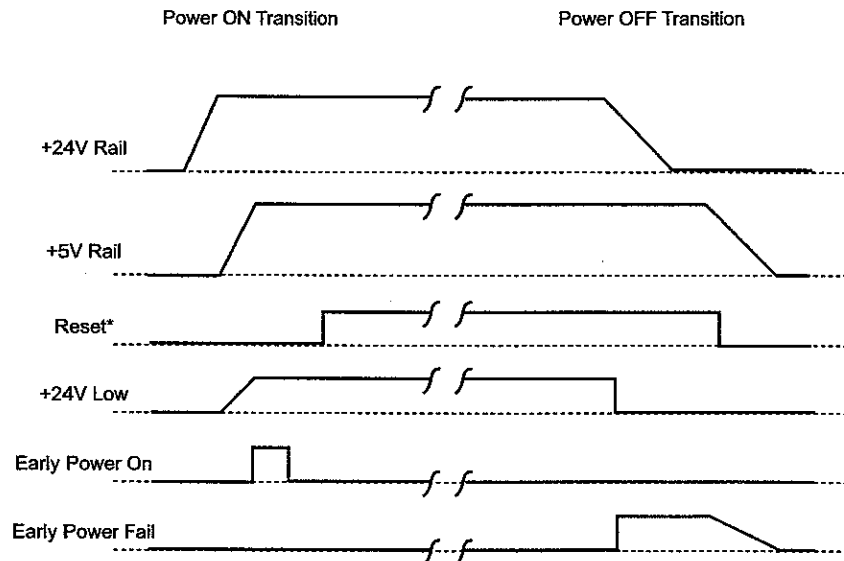
Figure 30: CPU Parallel Interface

CPU Board

(Continued)

Safety Circuit

The Safety Circuit is responsible for generating the three signals Reset, EPO (Early Power On), and EPF (Early Power Failure). It also includes a watchdog timer that generates periodic resets when the processor fails to pet the watchdog in time. Most of the Safety Circuit uses the +24V and +5V power rails to generate its outputs, because they are associated with power transitions, (see figure 31).


Figure 31: Power Transitions

First to be discussed are the events in the power on transition. As the +24V rail exceeds the converter's input hysteresis threshold (about 20 VDC), the +5V rail begins ramping up. The signal +24V Low* (active low) is now at a logic high, but must follow the +5V ramp upward. The Reset* line is active low. After the +5V rail exceeds the reset threshold of 4.6V, the power on reset time begins. About 100 ms to 150 ms after this point, Reset* goes high (is de-asserted). The signal EPO which is active high generates a pulse at the power on of +5V. The signal EPF (also active high) is quiescent during the power on transition.

In a power off transition, the +24V rail begins to decline. When it reaches the power fail threshold of approximately 20 volts, EPF goes high. Since the DC-to-DC converter shuts down at a lower point than its turn-on point, it can continue to generate +5V from energy stored in the input capacitor. EPF occurs at least 4 ms before the decline of the +5V rail. The EPF signal goes to the microcontroller's NMI (non-maskable interrupt) input. Therefore, it has enough time to do an orderly shutdown before Reset* occurs. Simultaneous with the EPF transition, +24V Low* is asserted. This is useful to the microcontroller during the EPF interrupt service routine. In the instance of a brownout, +24V Low* is active but Reset* does not follow. By monitoring +24V Low*, the processor may restart normal code execution and avoid a shutdown. When it is a true power failure, Reset* goes active as the +5V rail descends through 4.6V.

Theory of Operation

Whenever the +5V rail descends below the Reset threshold, Reset is asserted. A powerup reset is active for approximately 125 ms.

The open-collector Reset function is important to the microcontroller. It may execute a reset instruction, and thereby restart its own code execution. The microcontroller IC has an internal open collector transistor driver on the reset line for that purpose. A glitch on this signal trace has a powerful effect, so it must be protected from noise or ESD. It is recommended to buffer this signal before going off-board, in both Main and Remote versions.

The hardware watchdog timer function completes those of the Safety Circuit. Figure 32 illustrates the timing of the circuit.

CPU Board (Continued)

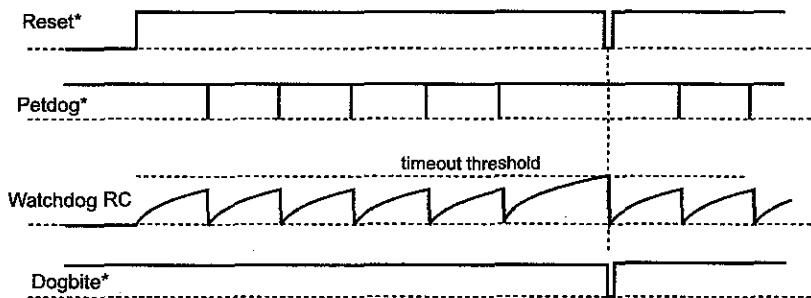


Figure 32: Safety Circuit Timing

The hardware watchdog timer begins its time-out as soon as powerup occurs. When Reset* ends, software execution begins. The watchdog timer expects periodic, active low pulses on the signal "Petdog" from the CPU Core as an indication of proper code execution. The timing diagram shows five such pulses after the end of Reset*. The EC voltage resets to zero on each pulse. After the fifth "Petdog" pulse, there is a lapse from an apparent software failure. This permits the Watchdog RC voltage to reach the time-out threshold. The watchdog timer then issues a "Dogbite" signal that tells the reset circuit to generate a Reset* cycle. The watchdog timer is self-resetting, bringing the Watchdog RC voltage to zero again. This Reset* cycle caused software execution to start over, and successful Petdog pulses once again pet the watchdog.

CPU Board

(Continued)

Communications Circuit

The communications circuitry makes it possible for a Remote Unit to control a Main Unit from up to 100 feet away. It also permits remote control of the Main Unit through telephone lines by offering a modem port. The circuitry itself is fairly straightforward, but the physical differences in the main and remote versions of the CPU Board are not as obvious.

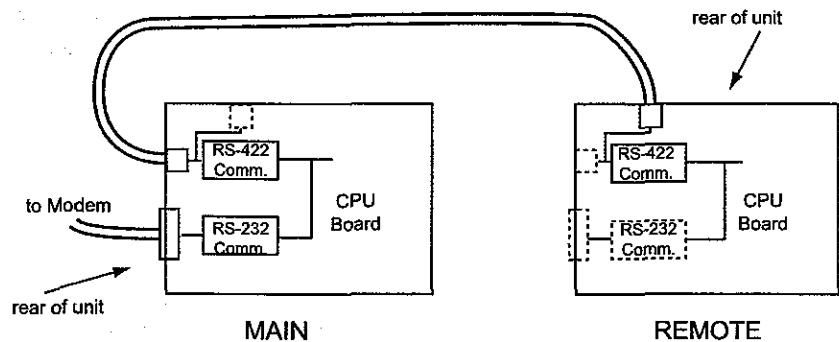


Figure 33: Illustration Unavailable at this Time

The Main and Remote Units have the same CPU (bare) Board, but they are populated differently as shown. The communications connectors are located along the edges of the CPU Boards to mate with external cables. The CPU Board features two sites for the Main-to-Remote connectors, which is a PCB mount 8-pin circuit DIN type (similar to keyboard connectors on PCs). On the main version it is located along the left edge of the CPU Board, which adjoins the rear of the main chassis. On the remote version it is located along the top edge of the CPU Board, which adjoins the rear of the remote console box. On the CPU Boards, the same RS422 transceiver connect to each of the connectors. However, the connectors are wired differently. The transmit pair of signals swap with the receive pair, from one connector to the other. This makes it possible to use a "straight-cable". On the Main Unit, the RS232 circuit is populated and goes to a 15-pin D-shell connector.

Note that the microcontroller on the CPU Board has only one serial port. The transmit line sends simultaneously through both remote and modem circuits. However, the receive lines must have a logical switch so the microcontroller listens to only one device at a time. The default is to listen for a Remote Unit. The modem communications has a special provision that detects the existence of a modem connection via a loopback wire. When detected, it automatically disconnects the receive line from the Remote Unit, and connects the modem receive line. On the remote version, neither the modem circuit nor its connector are populated. The receive switch is hardwired for main-to-remote communications.

Theory of Operation

PWM-to-Analog Output Circuit**CPU Board**

(Continued)

The 80C196 microcontroller features several pulse-width modulated (PWM) outputs. Some electromechanical devices can use pulses directly. However, the PSV includes a circuit to convert these to more useful (relatively steady-state) analog voltages. Five PWM channels (numbered 0-4) are used. Software in the CPU controls the output pulse width by writing to a register for each channel. Channel 0 has 8-bits resolution, and channels 1-4 have 10-bits resolution. Special timers and associated dedicated logic read these registers and output a periodic pulse whose width is modulated according to the value in the corresponding registers. This process is interrupt-driven, so it is somewhat transparent to the main and slower CPU tasks. Figure 34 shows a block diagram representation of the PWM-to-Analog conversion process.

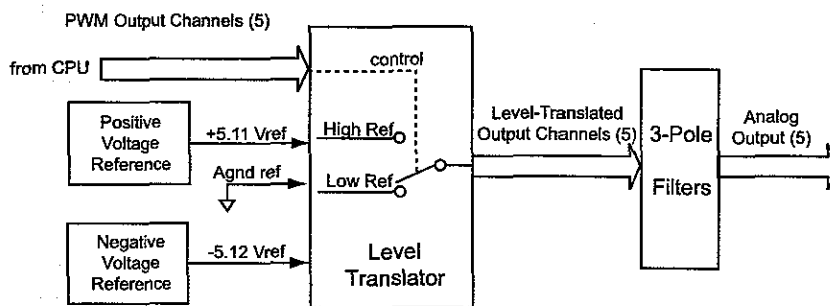


Figure 34: *PWM-to-Analog Conversion Process*

The level translator is the heart of the conversion process. It consists of five SPDT analog switches. Each PWM channel controls a switch, causing it to make/break according to the present duty cycle of the output. In this way the output of each switch spends a certain percentage of the time connected to its "High ref" input, and the remainder of the time to the "Low ref" input. There are three possible reference voltages that can be connected to the level translator for its switch inputs. A positive reference (+5.11V), a negative reference (-5.12V), and analog ground are available. Most switches are permanently wired to the appropriate references, but two of the channels have jumperable low reference switch inputs. The maximum available span of -5.12 to +5.11V gives 10.23 volts total, or 0.01V per LSB for the 10-bit channels.

The desired analog signal bandwidth is 1 Hz. That is, it is desired to pass a 1 Hz sine wave with less than 1 LSB distortion due to filtering. The PWM switching rate is approximately 720 Hz. The 3-pole filter Bode-plot break point is at about 60 Hz, yielding the proper results.

Theory of Operation

Control Board

▼ The primary role of the Control Board in the PSV operation is to control the air pressure delivered to the patient. It receives the waveform generator output from the CPU board as the desired pressure profile. And, it receives actual pressure and flow data from the Sensor Board. It compares the desired pressure with the actual pressure, and continuously regulates power to the blower motor and regulator valve actuator in such a way that the delivered pressure follows the commanded pressure. The Control Board (and Sensor Board) is therefore only applicable to the Main Unit. Because of this and circuit board area constraints, it also contains auxiliary functions that apply only to the Main Unit electronics, and they include Flow Signal Processing, Alarm Logic Circuitry, and Power On/Off Control.

The Control Board contains various complex circuits, not all of which are strongly inter-related. In this situation it seems best to offer two levels of block diagrams of the Control Board. A simplified top-level block diagram is shown in figure 35, containing seven objects.

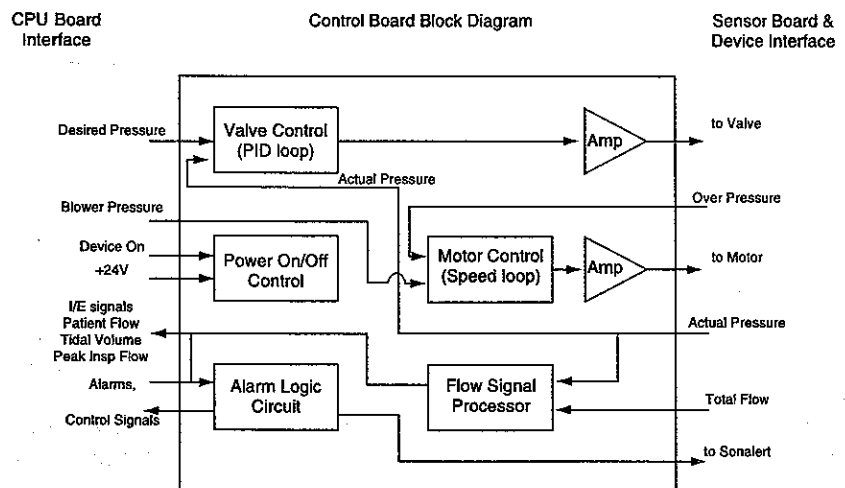


Figure 35: Control Board Block Diagram

Theory of Operation

Flow Signal Processor

The basic task of the Flow Signal Processor is to generate I/E (Inspiration/Expiration) signals to help the CPU Board's pressure waveform generator's timing of pressure changes, (see figure 36). Additionally, it extracts information from the Total Flow signal to deliver the signals Patient Flow, Peak Inspiratory Flow, and Tidal Volume. It uses the device output pressure, or Patient Pressure, to help compensate for changes in non-respiratory flows.

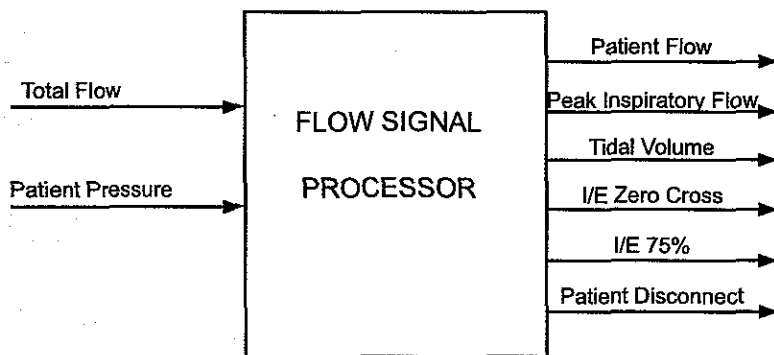
Control Board
(Continued)

Figure 36: Flow Signal Processor

The device features modes of operation that raise the patient pressure during the patient's natural inspiration, and lower it during the subsequent expiration. Various means are available to monitor patient inspiratory effort. Like many ventilator-class devices, the PSV uses the non-intrusive patient air flow method. That is, the PSV's I/E Detector Block continuously monitors air flow levels out of the blower into the valve. Signal processing techniques separate leak flows from patient flows, set an inspiratory threshold, and generate timing pulses corresponding to the inspiratory and expiratory phases of respiration.

Inspiration/expiration detection is a key function of the PSV. Discerning inspiration from expiration must be reliable enough for continuous use, as it actually controls the delivered pressure. There are some "patient data" variables such as tidal volume, peak inspiratory flow, and so on that are displayed on the front of the PSV in numerical form. These are called "estimated parameters", and their values are not as precise as the I/E detection. They are made available to the physician or therapist who will watch for trends or otherwise evaluate the parameter values in a larger context. Indeed, the determination of inspiration and expiration must be more precise, as it does not encompass a sanity check by a live attention.

Control Board
(Continued)

In the PSV device architecture, the flow meter is located between the blower and the pressure regulator valve, (see figure 37).

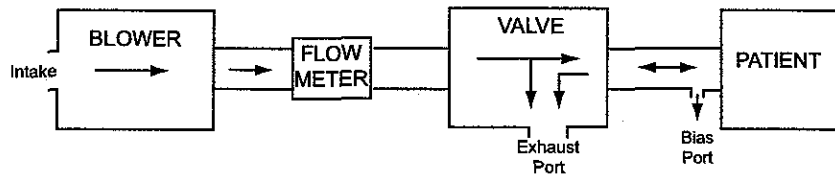


Figure 37: Flow Meter Location

The other possible location is between the valve and patient. However, the flow meter location shown above is a function of the following concerns:

1. The flow meter may be more easily be kept clean of possible fluids in the patient hose.
2. An industry patent exists on "averaging" inspiration and expiration levels to compute I/E signals. Direct measuring of expiration flows may be construed as copying prior art.
3. The characteristic resistance of the flow meter to a person trying to exhale might be objectionable high.

During inspiration, the valve opens enough to elevate the patient pressure to the support level. When the patient is ready to exhale, the flow level decreases, and the valve closes. However, the exhaust port on the valve simultaneously opens to atmosphere, which ensures the lowering of patient pressure to the required level. Because air is dumped overboard, the flow meter does not see that flow directly. Consequently, the observed flow during expiration is diminutive, compared to the magnitude of the previous observed inspiration, (see figure 38).

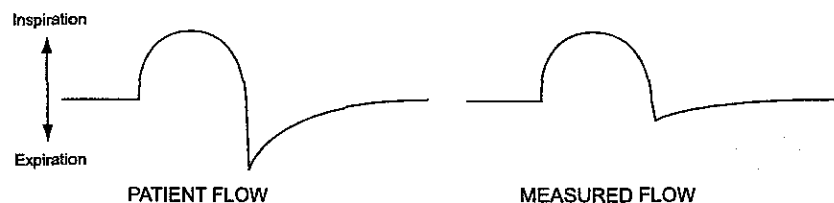


Figure 38: Expiration Flow

Theory of Operation

Nevertheless, the measured flow waveform does *something* during the expiration period. After all, the flow signal processor cannot separate something from nothing. Therefore, in these discussions “expiratory waveform” refers to the *measured* waveform of the flow sensor during the expiration period. Although significantly smaller than normal, the expiratory waveform is still useful. The worst case detection conditions are at low PEEP levels, where the bias flow leaks are small, (see figure 39).

Control Board (Continued)

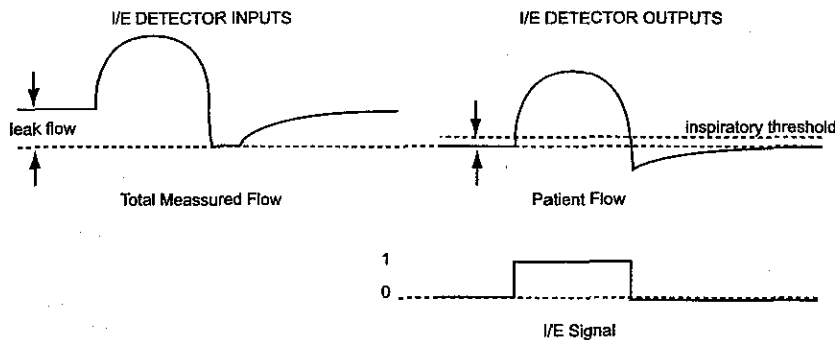


Figure 39: Expiratory Waveform

Because the exhaust port on the valve relieves reverse flow, the flow sensor does not see absolute negative flows. In the left waveform in figure 39, the negative peak at the start of expiration has been truncated. On the right is the Patient Flow output of the circuit, which has the leak flow component removed. The inspiratory threshold, set at about 0.32L/s, is shown just above the zero patient flow line. At the lower right is the resultant I/E signal. When the patient flow waveform exceeds the inspiratory threshold, the I/E signal changes state. In actual circuit implementation, hysteresis causes the threshold to lower slightly once Patient Flow has risen above the threshold level.

I/E Detection Principles

The basic principle of the I/E detection circuit is that for a given patient breathing normally, an inspiration is useful in predicting the subsequent expiration, more so than the converse. There is a proportional relationship between the inspiratory length of time and amplitude (volume of air inhaled) and the same parameters for the expiration of the same breath. Using this principle certain expectations for the expiration waveform can be set up. During the expiration phase, differences are attributed between the expected and actual expiration waveform to changes in leak flows. Adjusting out the differences by slowly changing the leak offset value throughout expiration. By making these corrections in real time, a tracking-type loop is formed. The inspired volume is used to form a model of the expected expiration, (see figure 40).

Control Board

(Continued)

During inspiration, the tracking circuit creates a tidal volume (inspired volume) value. Notice in the figure the arbitrary inspiratory waveform containing two different levels. Below, the tidal volume accumulates in the negative direction. Its varying slopes show how it responds to inspiratory activity. The greater the inspiratory flows, the greater the rate of tidal volume accumulation. In a passive exhalation, humans create a roughly exponential flow waveform. When inspiration ends, the negative tidal volume value is the starting point for its exponential ascent back to zero value.

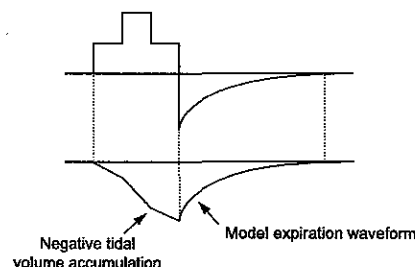


Figure 40: Expiration Model

In a previous section we discussed the fact that the expiration waveform is diminutive in the PSV because of the physical location of the flow sensor. Yet, the constant bias flow at the mask elevates the Total Flow waveform to see *some* expiration activity. In the actual circuit, the expiration model is attenuated from the ideal to match the smaller observed flow levels. In other words, the model has been adapted to see expiration flows as the PSV sensor presents them. Though now small, the space between the model and the non-respiratory flow line is valuable area within which to do error correction and null out leaks. Undoubtedly, seeing less of expiration than is actually occurring fundamentally limits that rate of change of leak flows that may be nulled out. However, the tracking strategy can still be effective because the model works both in amplitude and time. The most important aspect of the model is that regardless of initial amplitude it converges to zero, as any exponential model does.

Tracking Loop Corrections

Creating an expiration model that is proportional to the preceding inspiration is a key part of the tracking circuit's ability to null out non-respiratory, or leak flows. For example, suppose the patient breathes normally, but an additional leak flow develops during inspiration, (see figure 41). The additional positive flows create an exaggerated tidal volume value. The dashed line waveforms are those that would occur if the tracking circuit corrections did not intervene. While circuit corrections did not intervene. While expiration activity still pushes the waveform below the inspiratory threshold into expiration, the new positive offset causes the expiration waveform to ascend above the threshold prematurely.

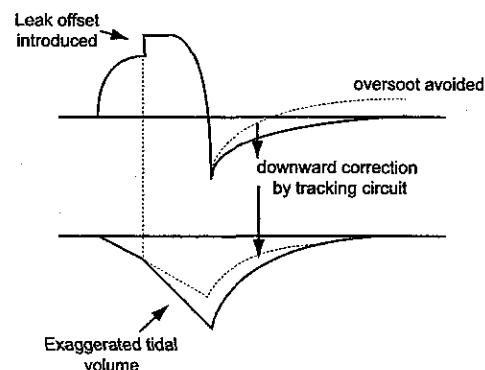


Figure 41: Expiration Model

Theory of Operation

However, the exaggerated tidal volume makes the expiration model larger (more negative). The model then applies downward corrections on Patient Flow (same as increasing leak flow estimate). In this way, the leak is nulled out in early expiration. A false inspiratory trigger is avoided. The correction scenario is similar for a reduction in leak flow.

Control Board (Continued)

The respiratory waveform tracking loop necessarily has built-in boundary conditions. That is, invalid or confusing waveforms must be handled gracefully so that tracking can resume whenever normal respiration activity resumes. First of all, the inspiration period is limited to about 4 seconds (Note: This is easily confused with PSV firmware's limiting pressure support periods to 3 seconds). If the Patient Flow waveform stays above the inspiratory threshold from more than 4 seconds, a "reset" timer causes the circuit to declare the present flow level as the new non-respiratory (or, zero) flow. This causes the I/E signal to return to the expiration state. There is no expiration time limit, so expiration may theoretically be infinitely long. This makes expiration as the natural resting state of the tracking circuit.

It is useful to understand tracking circuit operation by examining boundary conditions and traction corrections in terms of "zones", (see figure 42).

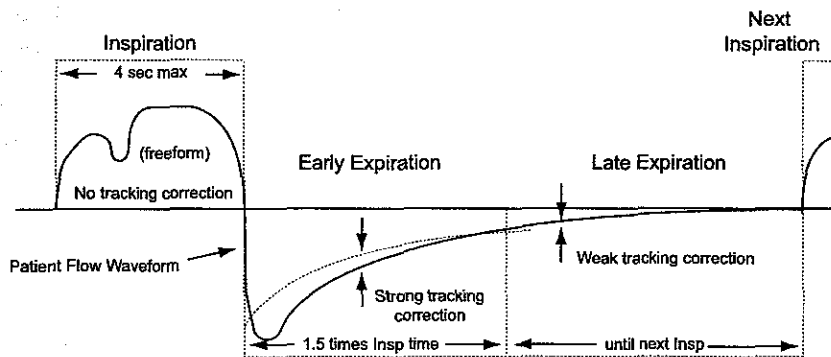


Figure 42: *Tracking Circuit Zones*

The tracking cycle for a single breath consists of Inspiration, Early Expiration, and Late Expiration. To enter the Inspiration zone, the Patient Flow waveform crosses the inspiratory threshold. During inspiration zone, no corrections to leak flow are made. An odd-looking inspiratory waveshape is shown in figure 42, indicating the flow signal may exhibit any freeform flow, as long as it descends through the inspiration threshold before 4 seconds pass.

When the expiration phase begins, the tracking circuit begins to make corrections to the estimated leak flow level. These are in effect until the next inspiration begins. The model expiration waveform is synthesized while the actual one progresses. They are compared, and any difference is treated as an error. The leak offset is adjusted on a continuous basis until the difference no longer exists, or until the next inspiration has begun. Notice that the expiration phase is divided into two zones: Early and Late Expiration. These are actually a two step linearization of a probability continuum. Stated simply, we do not know precisely when the next inspiration is going to occur.

Control Board

(Continued)

However, the I/E ratio is more typically 1:2, regardless of breath rate. In the time just after expiration begins, it is least probable that a new inspiration occurs. As time passes, it becomes increasingly probable that a new inspiration will occur. This advantage is used by multiplying tracking errors by a larger gain during early expiration, and by smaller gain during late expiration. It is important to note that when the patient does actually try to start a new breath, the slope of the flow waveform has to outrun the tracking circuit's rate of correction (otherwise, their attempt to inhale into the freeform area of inspiration is nulled out as leaks). So, by making the strongest leak corrections during early expiration, the error gain is lowered and sensitivity to shallow breathing (weak inspiratory efforts) is maintained.

The time of inspiration is stored in an analog timer. During expiration, the timer is reversed at a slower rate, 1.5 times the inspiratory time. Its time-out is used to separate Early from Late Expiration. The constant of 1.5 is chosen because it allows Early Expiration to end before most I/E ratios have the next inspiration begin. If the patient's I/E ratio falls below 3:2 then the Late Expiration zone is bypassed as the tracking circuit cycles. This is normal, because the usual cause for short expiration periods is when expiration is forced (as in heavy breathing), rather than passive. This results in higher flow signal amplitudes, further enhancing tracking ability.

Actual I/E Signals

So far the I/E (Inspiration/Expiration) signal concept has been simplified to facilitate the introduction of tracking methodology. Now specifically, the I/E Detector creates two distinct logic-level "I/E" signals. Each signal goes to the CPU Board for use by the microcontroller, (see figure 43). The signals are called "I/E Zero Cross" and "I/E 75%". In terms of indicating inspiration activity, both are inverted (low during patient inspiration). Both signals go to the active state when Patient Flow exceeds the inspiratory threshold. Circuitry ensures the leading edges are aligned. When Patient Flow returns to the non-respiratory flow level (actually the inspiratory threshold), I/E Zero Cross is de-asserted. The purpose of this signal is for the microprocessor's use in doing patient data calculations. It

is for real-time use in discerning inspiration from expiration. The second signal, "I/E 75%", is used in pressure control. The leading edge tells the waveform generator that it is time to raise the pressure. This aids the patient inspiration. The trailing edge has a timing "advance" feature. When the inspiratory flow (Patient Flow only) drops to 75% of its peak value, I/E 75% is de-asserted to the expiration state. This permits the pressure waveform generator to lower the pressure in time to actually aid the patient in expiration. This timing advance is important, because patient effort is applied to inspiration, while expiration is passive. Without it, the PSV would inflate the lungs and hold the pressure uncomfortably long until the flow level finally dropped.

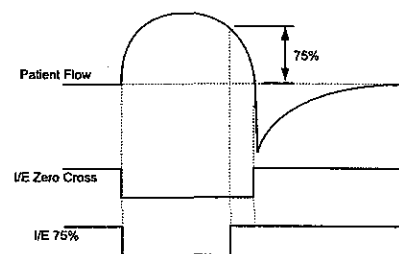


Figure 43: I/E Signals

Theory of Operation

Tracking Loop Implementation

At the upper left of figure 44, the Total Flow provides the input for respiratory tracking. This point is after the pressure compensation stage for variations in leak flow at the bis port. The differentiator/integrator pair pass the signal straight through, minus the current leak flow offset stored in the integrator. The peak detector and inspiration threshold boxes produce the two I/E signals. The I/E zero cross is used internally in the tracking circuit. It tells the tidal (inspiratory) volume integrator when to integrate. The tidal volume output is used externally, but it also goes to the expiration model generator. The I/E signal tells the model when to go into action. Its output and the Patient Flow signal enter a difference node that feeds a variable gain stage. The inspiration timer controls its gain, depending on whether the phase is inspiration, early expiration, or late expiration. Inspirations that last more than 4 seconds result in a reset of the integrator, effectively declaring late expiration and setting the current Patient Flow to zero.

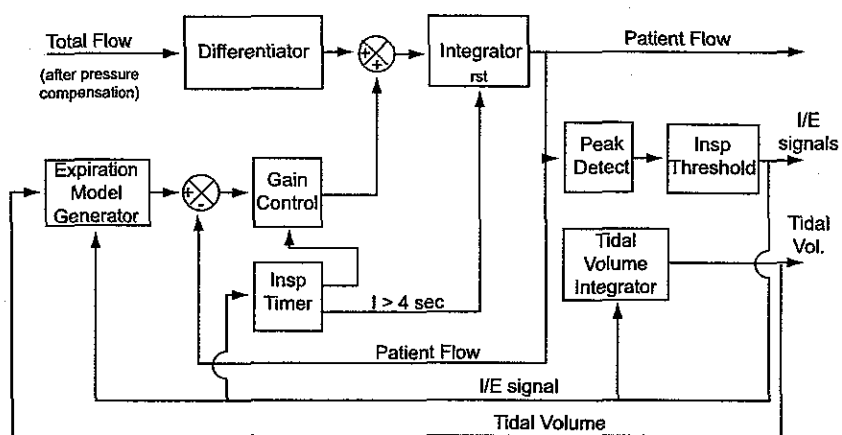
Control Board
 (Continued)


Figure 44: Tracking Loop Diagram

Patient Data Signals

Part of the task of the Control Board's analog flow signal processing is to provide flow-related patient data to the CPU Board for each patient breath cycle. They include the two analog signals "Tidal Volume" and "Peak Inspiratory Flow". Both signals are naturally generated as part of the tracking circuit. These signals are illustrated here because they must have a consistently useful form for use by the CPU Board, (see figure 45). The waveforms begin assuming all variables are currently zero, and the first breath after $t=0$ has

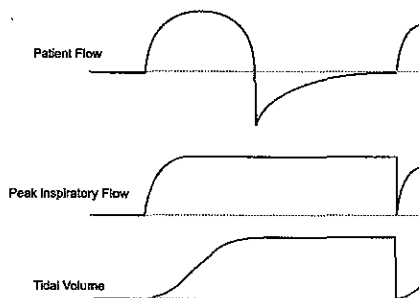


Figure 45: Data Signals

Theory of Operation

Control Board

(Continued)

now arrived. Peak Inspiratory Flow follows Patient Flow exactly, and holds the peak value throughout the following expiration. At the beginning of the next inspiration, the peak hold value is reset to zero. It is quickly released in order to track the next inspiration. Similarly, Tidal Volume (or inspiratory volume) accumulates during inspiration by an integrator function. Its value is held throughout expiration. It is also reset and released upon the detection of the next inspiration. The CPU on the Control Board uses the I/E Zero Cross signal to coordinate the reading of valid data from these variables. Immediately after expiration begins, the values are read and displayed on the front panel.

Notes:

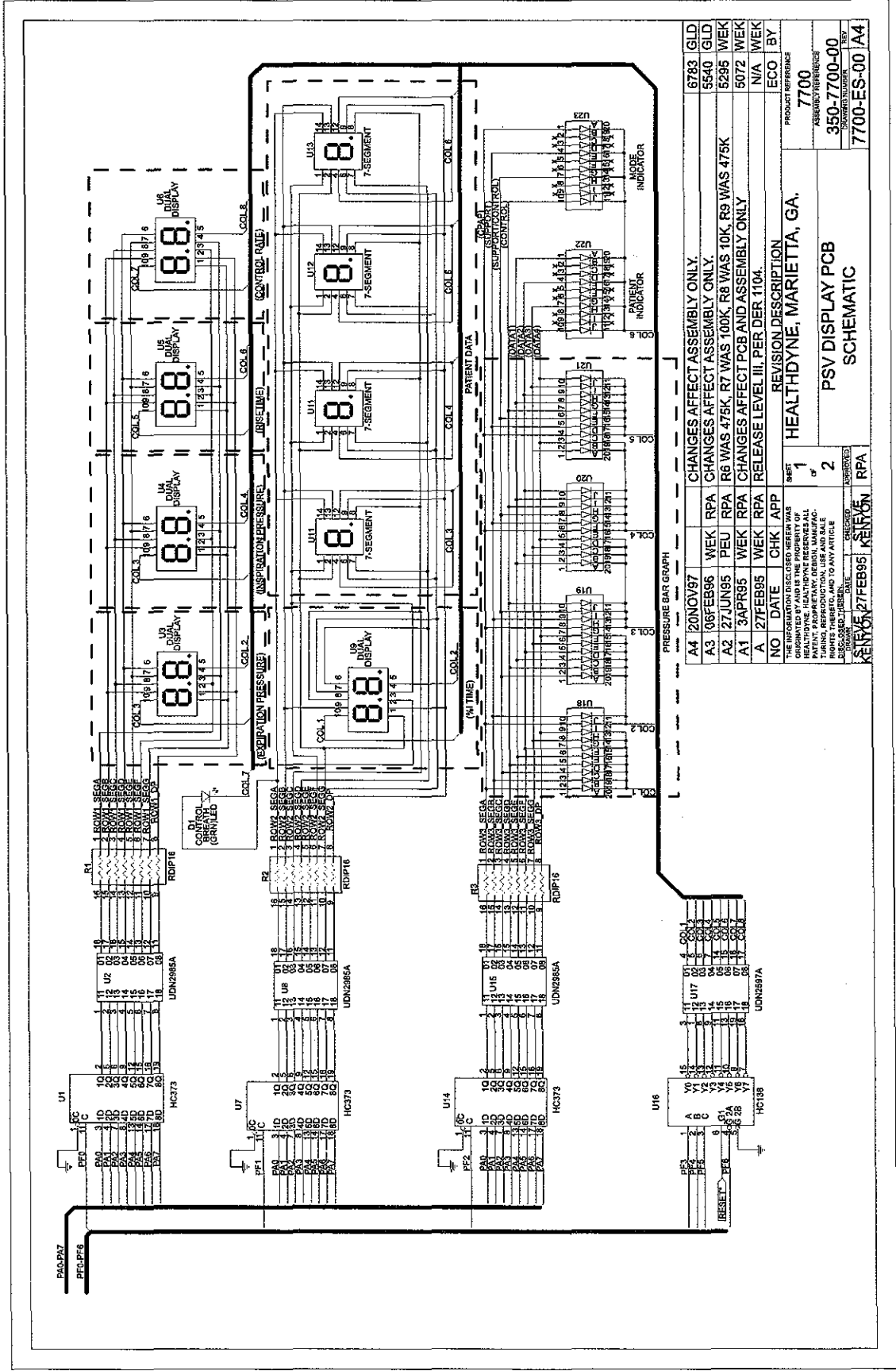
Schematics

Section 13.0

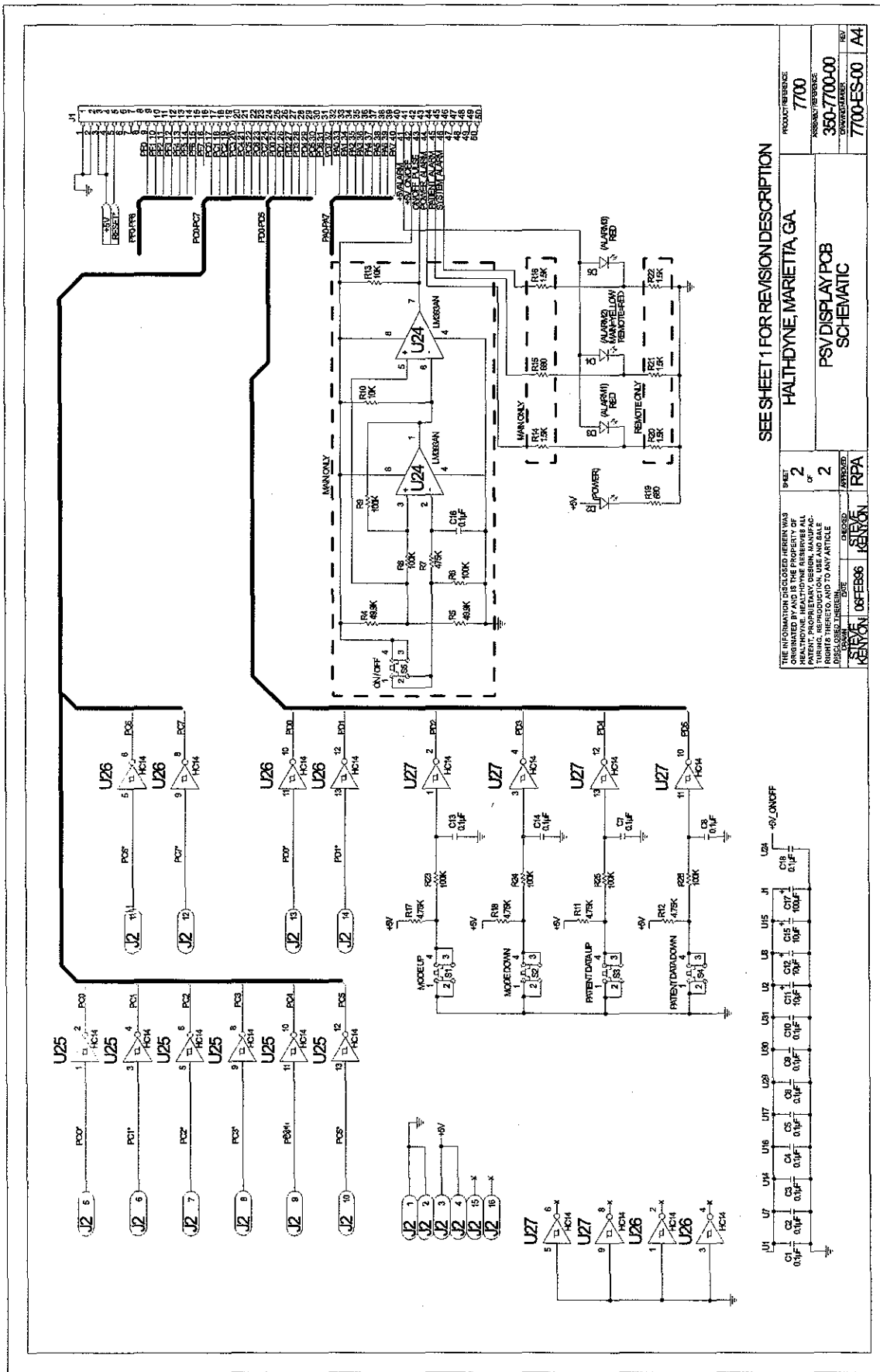


SECTION 13.0 Schematics

Notes:



Notes:



SEE SHEET 1 FOR REVISION DESCRIPTION

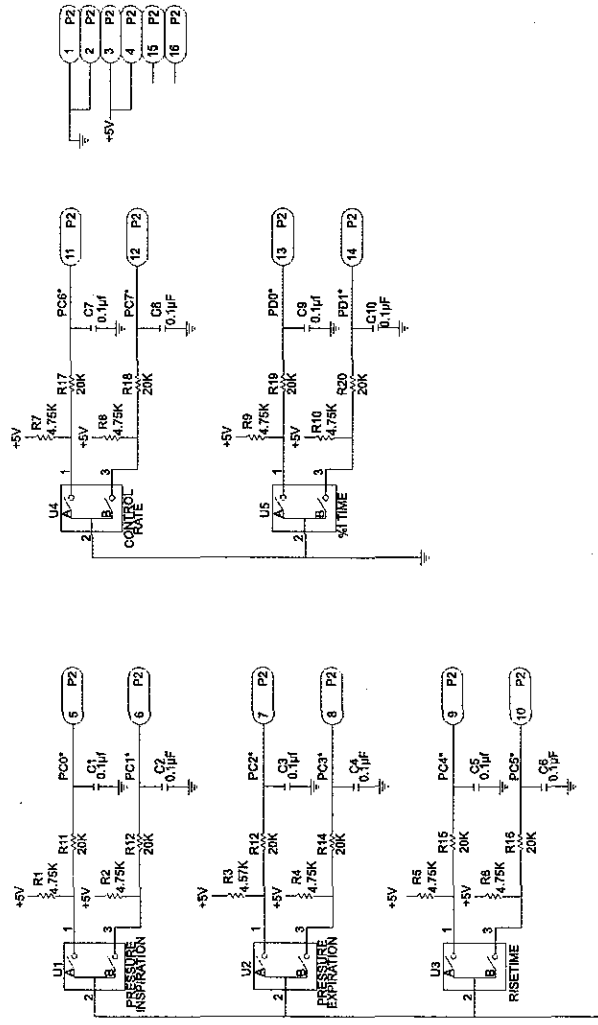
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PSV DISPLAY PCB SCHEMATIC		7700-ES-00		A4	
PRODUCT NUMBER		7700		350-7700-00	
REVISION		08 FEB 88		08 FEB 88	



SECTION 13.0

Schematics

Notes:



CHANGES AFFECT ASSEMBLY ONLY				6783	GLD
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PSV ENCODER PCB				350-7700-10	
SCHEMATIC				7700-ES-10 A1	
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A	24FEB95	CHK	APP	1	1
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